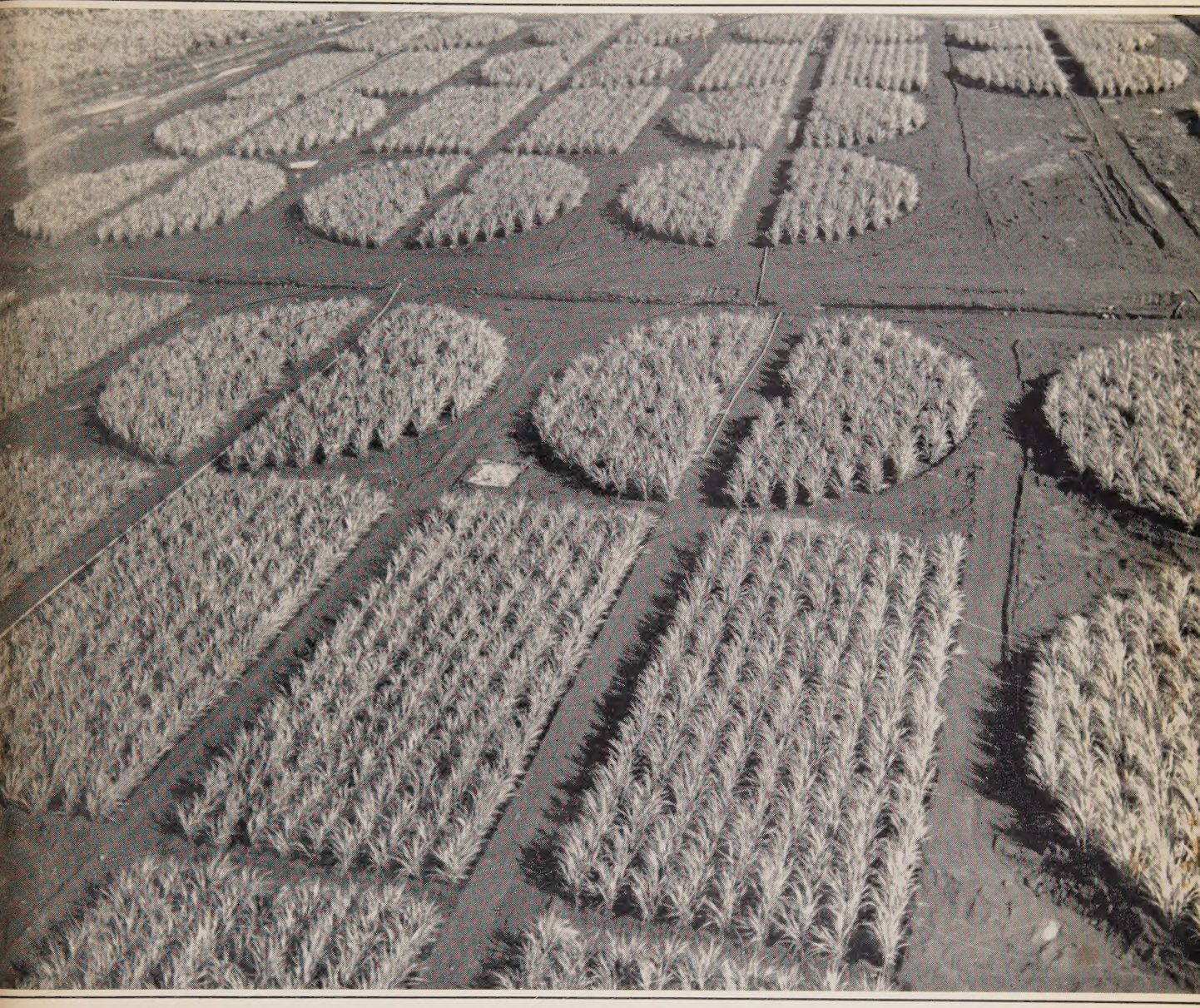
HAWAIIAN SUGAR PLANTERS' ASSOCIATION



EXPERIMENT STATION REPORT

1959

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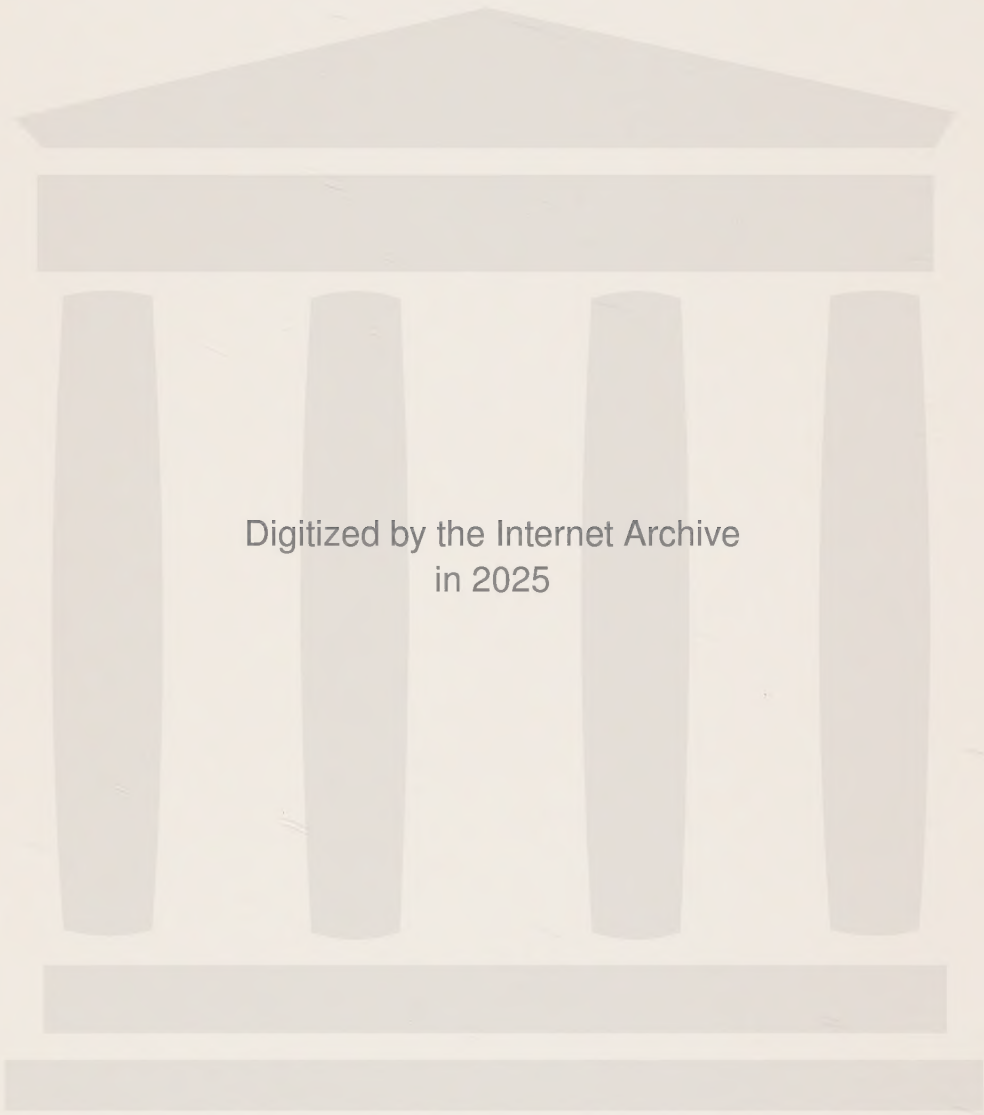
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THE EXPERIMENT STATION
HAWAIIAN SUGAR PLANTERS' ASSOCIATION

REPORT

October 1, 1958 to September 30, 1959

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ON THE COVER:

Irrigation experiment MASI
Field No. 408, HC&S
(*Courtesy HC&S Co. Breeze*)

HAWAIIAN SUGAR PLANTERS' ASSOCIATION

To The President and Members

Gentlemen:

This Experiment Station Report for the year ending September 30, 1959, contains the results of some very high quality research which has been performed by a most competent staff, and which should have considerable impact upon the solution of the many problems within the Hawaiian sugar industry. Although the contents of the Report should speak for themselves, it is important to point out the many cooperative efforts that have made this research possible. In enumerating some of the more important cooperative ventures, we must also give credit to the excellent cooperation between the Experiment Station personnel and the plantations in practically all the aspects of our research program.

The most comprehensive cooperative research has been the cane diffusion pilot plant at Kekaha Sugar Company. In addition to the plantation, we have had the closest cooperation with the Silver Engineering Works, the Rietz Manufacturing Company, the Gruendler Crusher and Pulverizer Company, the Merrick Scale Company, and the French Oil Mill Machinery Company, who have contributed close to $200,000 of special equipment to the project. We have progressed rather rapidly in obtaining information, and we hope to be able to complete the research by the middle of 1960.

Another example of important cooperation between the plantations and the Station has been the design, development and successful field trials of the seed cane harvester at Kohala Sugar Company. This project has moved along especially well, and it is now possible to mechanize the whole operation from the cutting of the seed to its planting in the soil.

The cooperative irrigation research at Hawaiian Commercial and Sugar Company on Maui covers several very important areas. The comprehensive installations on evapotranspiration to determine the water consumption of the cane plant have been yielding most valuable data. We have reached the point where we are prepared to recommend to plantations the installation of evaporation pans to evaluate the evapotranspiration under their respective climatic conditions.

The comprehensive experiment called MASI is providing information on the comparative effect on cane yield of surface and overhead systems for applying water. More recently, in cooperation with the John Bean Division of the Food Machinery Chemical Company, the Shur-Rane Sequa-Matic method of overhead irrigation has been installed on 14½ acres of cane land at HC&S. All of these experiments are contributing specific information for evaluating both overhead and surface irrigation systems.

The cooperative research with the Shell Chemical Company in the study of nematodes and their effect on sugar cane has been expanded to include the University of Hawaii. When Dr. Walter J. Apt, Associate Nematologist of the United States Department of Agriculture, returned to the Mainland after spending six months with the Experiment Station, the Hawaii Agricultural Experiment Station was contacted to assist in the continuation of the work.

The cooperative research with the USDA in the physiology of cane flowering has resulted, for the first time, in the successful induction of flowering of 37-1933 during the early summer. This is quite an advantage since it permits crossing 37-1933 with earlier tasseling canes, which will widen the possibilities for the development of new varieties of cane for Hawaii.

On September 8, the Experiment Station, in cooperation with the Pineapple Research Institute, established a joint computing center. This center is under the direction of the Department of Experimental Statistics and is located in the basement of Lyon Hall. It is equipped with an IBM Automatic Decimal Point Computer. An IBM 964 Auxiliary Printing Tape Punch has been ordered and will be installed by the end of the year. This equipment is fed by paper tape but, via a card to tape converter, it can be fed data assembled in punched card installations. Programs are being developed for a wide variety of computer problems bearing on the research programs in sugar and pineapple. The machine will not only expedite the analysis of Experiment Station data, but will be available for analyzing plantation results.

Dr. Kenneth Sund has joined the staff as Senior Chemist and will be devoting his time to the chemical problems of weed control.

The Experiment Station staff was called upon twice during the past year to give technical assistance to plantations because of emergency problems. The first came as an aftermath of the strike in early 1958; the second followed the disastrous effects of Hurricane Dot on the island of Kauai. In both cases, teams of staff members assisted the plantations in developing procedures for evaluating losses and related effects.

During the year, 1908 new books have been added to the Library. Twenty-four microfilms and photoprints were added to bring this total up to 372.

Staff changes are listed on page 79.

Respectfully submitted,

R N Bauer

Director

CULTURAL PRACTICES

CROP LOGGING STUDIES CONTINUE

Only 30 experiments were selected for sampling as a result of the strike. Many experiments had to be discarded.

The experiments harvested continue to show the potassium levels in the sheath and 8-10 stalk tissues to be equally sensitive in indicating the potassium needs of the cane plant.

Three more calcium experiments were harvested during the year, and when their 8-10 stalk calcium levels were included with those of the five calcium experiments harvested earlier, the adequate calcium level was confirmed at .050 per cent. The adequate sheath calcium level is .15 per cent as tentatively established in the 1957 Annual Report.

JUICE QUALITY TEST PRODUCES PRELIMINARY DATA

The harvest of the juice quality test (Group Test 33) on the island of Oahu is nearly completed with five of the seven tests harvested. The yield data from the five experiments harvested to date suggest that the optimum nitrogen level is between 200 and 400 pounds. The higher amounts of nitrogen produced trends for lower juice quality in most of these tests (Table 1), while the effect of timing of nitrogen on juice quality appeared to vary with plantation and variety.

Table 1. Juice Quality Test Harvest Results (Mean of 5 tests harvested)

Lbs N/A	TCA	Y%C	TPA
200	113.1	14.7	16.7
400	119.1	14.2	16.8
600	123.2	13.6	16.6

Microplot samples have been collected prior to and after burning to evaluate the juice quality changes, if any, due to burning. Elaborate separation of the various orders of stalks and the various parts of stalks has been made on all microplot samples in an attempt to gain more insight into the effects on juice quality of these various segments of the crop. Nutrient analyses were also made on various orders and parts of stalks to provide information on uptake and distribution of nutrients in the crop. It is planned to have statistical analyses of this study done on the recently acquired IBM equipment.

WHAT ARE OPTIMAL FERTILIZER LEVELS?

This study is a joint project between the Agronomy and Experimental Statistics Departments. Most of the attention has been focused on the relationship between soil levels of potassium and yield responses in tons of pol per acre. The findings indicate that responses of 0.198 or 0.142 TPA per 100 pounds of K are required to yield a 10 per cent profit on the fertilizer investment, depending on whether or not labor costs, including employee benefits, are taken into account. A return of 0.236 TPA is required to ensure a 20 per cent return, where labor costs are considered. This is somewhat descriptive of the approach taken, the main objective being to translate experiment yields and soil analyses into a form which would be readily interpretable to technician and to management.

REFINEMENT OF CRITICAL LEVELS FOR SOIL PHOSPHORUS, POTASSIUM, CALCIUM AND MAGNESIUM

During the year, 250 soil samples from field experiments were analyzed principally as a check on the validity of already established limits of response to fertilization. These limits, which remain unchanged for P and K and which are newly defined for Ca (Figure 1), are as follows:

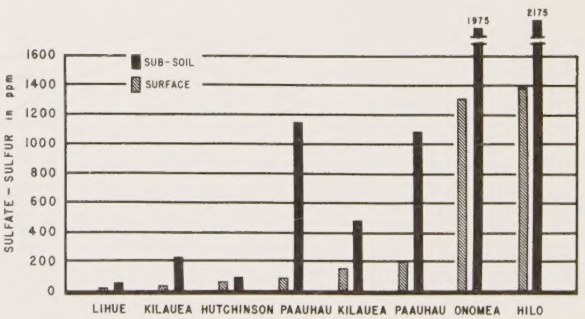


Figure 1. Sulfur appears generally to be at higher levels in the subsoil than in the surface soil.

Phosphorus: (Truog)	Probable response—below 25 pounds P per acre-foot Uncertain response—25 to 45 pounds P per acre-foot Improbable response—above 45 pounds P per acre-foot, except in instances of restricted root development.
Potassium: (Exchangeable)	Probable response—below 200 pounds K per acre-foot Uncertain response—200 to 300 pounds K per acre-foot Improbable response—above 300 pounds K per acre-foot
Calcium: (Exchangeable)	Probable response—below 300 pounds Ca per acre-foot Uncertain response—300 to 400 pounds Ca per acre-foot Improbable response—above 400 pounds Ca per acre-foot
Magnesium: (Exchangeable)	Response has not been obtained to applications of Mg. Levels of Mg as low as 50 pounds per acre-foot appear adequate.

CALIBRATION OF MINOR ELEMENT ANALYSES

Spectrochemical analysis of plantation soils for minor elements and aluminum was continued in 1959. In an endeavor to standardize the results against plant response, a pot test was initiated with sugar cane planted in soils containing minimum amounts of minor elements and also in one soil unusually high in aluminum. Minor elements were applied as chelates both to the soil and to the foliage.

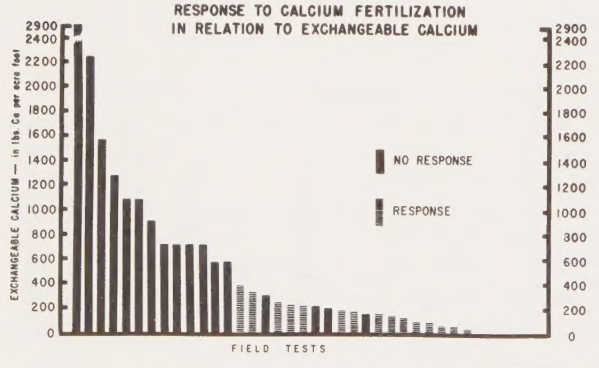


Figure 2. Sulfur levels in surface and subsoils of the Hawaiian sugar industry.

Response to applications of minor elements was apparent in certain instances in the early months of the study. In no case, however, has the differential persisted. Growth in the untreated soil high in aluminum has been equal to that in the same soil treated to minimize any possible toxic effect of this element. These studies are being expanded to ascertain any special role that aluminum plays under field conditions.

SULFATE-SULFUR CONTENT OF SOILS STUDIED

Additional data regarding the sulfur status of plantation soils were obtained during 1959. The content of sulfur in the soil appears to be a function of past fertilization with sulfate of ammonia and superphosphate, the sulfur content of the irrigation water, and the ability of the soil to retain applied sulfur.

Values for extractable sulfur range from about 15 to several thousand pounds per surface acre-foot. The highly leached soils which are generally low in most nutrients are not characterized by low levels of sulfur.

Unlike any of the other plant nutrients for which soils are ordinarily analyzed, sulfur appears to be at higher levels in the subsoil than in the surface soil. This is illustrated in Figure 2, where bars representing eight divergent soils are arranged from left to right according to increasing level of sulfur in the surface soil.

LEACHING LOSSES IN LYSIMETER STUDIES

Mean losses of nitrogen and potassium from the lysimeters at Hawaiian Commercial and Sugar Company at the end of the plant crop are shown in Table 2.

Table 2

Fld. No.	No. of Irrig. Rounds (Av.)	Lysimeter No.	Nitrogen	Potassium
			Lbs/A	Lbs/A
205	37	7, 8, and 9	105	210
405	35	4, 5, and 6	125	140
906	75	1, 2, and 3	165	310

Study is currently being made of losses of nitrogen and potassium from these lysimeters in the ratoon crop.

A lysimeter test has been initiated to determine the influence of soil temperature on the ability of the root system of sugar cane to minimize losses of plant nutrients by leaching.

EFFECT OF LIMESTONE ON SOIL pH

Study of the influence of ground limestone in field experiments has shown increases in pH in the kuakua consistent with increasing applications of liming material broadcast and plowed into the soil. Where limestone has been concentrated in the cane line, the pH at the end of the crop has sometimes shown less than the anticipated effect of treatment, owing primarily to the neutralizing effect of acid-forming nitrogen fertilizers.

NON-VOLATILE NITROGEN SOLUTIONS UNDER STUDY

The large price differential between aqua ammonia and the solid forms has resulted in the use of aqua ammonia as the principal source of nitrogen. Recent price reductions in the solid forms of nitrogen fertilizers have awakened interest in the use of these materials in high analysis, non-volatile solutions. Preliminary trials on Hawaii look promising.

Particular interest is shown on those plantations in the wetter, unirrigated districts where efficiency of aqua ammonia has been questionable.

DOES REPLANTING PAY?

What is a satisfactory stand? Several years ago, tests were installed at The Lihue Plantation Company, Ltd. to compare ratoon yields of fields cut by the Duncan harvester with push-raking. The stand in the plots cut by the harvester was far more complete than in the case of the push-raked plots. However, there were no differences in yield at harvest.

The high cost of replanting has focused attention on the need for "insurance" in getting a satisfactory stand. Replanting studies conducted at Grove Farm Company and Lihue during the last two years have shown no yield increases for replanting all gaps of three feet and over. The replant cane that did manage to survive in the three-, four- and five-foot gaps was small and spindly (Figure 3) and contributed little to the total yield. The stools established were very weak and their survival is being checked in the subsequent ratoons. Average sized stalks were obtained only when the gaps were seven feet and larger.

Figure 4 shows the terrific competition from nearby established stools as they begin to close in. The stalks from replant seed appear to "stand still" while the surrounding cane booms ahead, often resulting in mortality of replant cane.

Figure 3. Small, spindly cane from replant seed in Lihue Expt. 427 ER. Medium-sized stalk from replant seed in 7-foot gap shown on left.

Figure 4. Competition for sunlight intensifies as cane from surrounding established stools enters the "boom stage" of growth. Cane from replant seed stays weak and spindly.

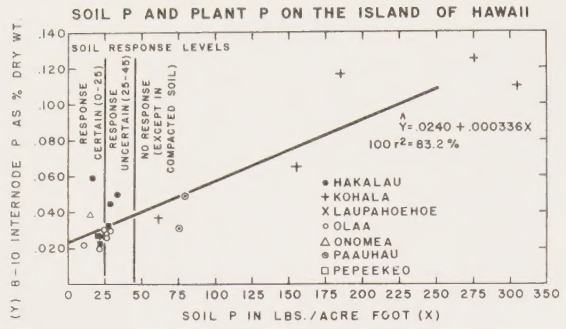


Figure 5. Soil P and plant P on the island of Hawaii. 8-10 internode P is that of the check plots.

TOTAL PHOSPHORUS IN INTERNODES 8-10 AS A GUIDE TO THE FERTILIZATION OF SUGAR CANE

Critical ranges of 8-10 internode phosphorus suggested by a study of significance of differences in tons sugar per acre in previous and current crops, were as follows:

.040 and more: P not needed
.032-.039: Borderline range, P perhaps needed
.031 and below: P needed

Agreement between these critical ranges of plant phosphorus and soil response levels as determined by the Agronomy Department is illustrated in Figure 5.

EFFECT OF CLIMATE UPON PHOSPHORUS METABOLISM

The variety 37-1933 was grown in the climate houses with two amounts of phosphorus (32 ppm P and 2 ppm P), three air temperatures (Makiki +9°, Makiki, and Makiki −9°), two root temperatures (62° and 72°), and two light conditions (full sun and half shade). At approximately eight months of age, the plants were photographed and harvested. Figure 6 shows an average plant from each treatment.

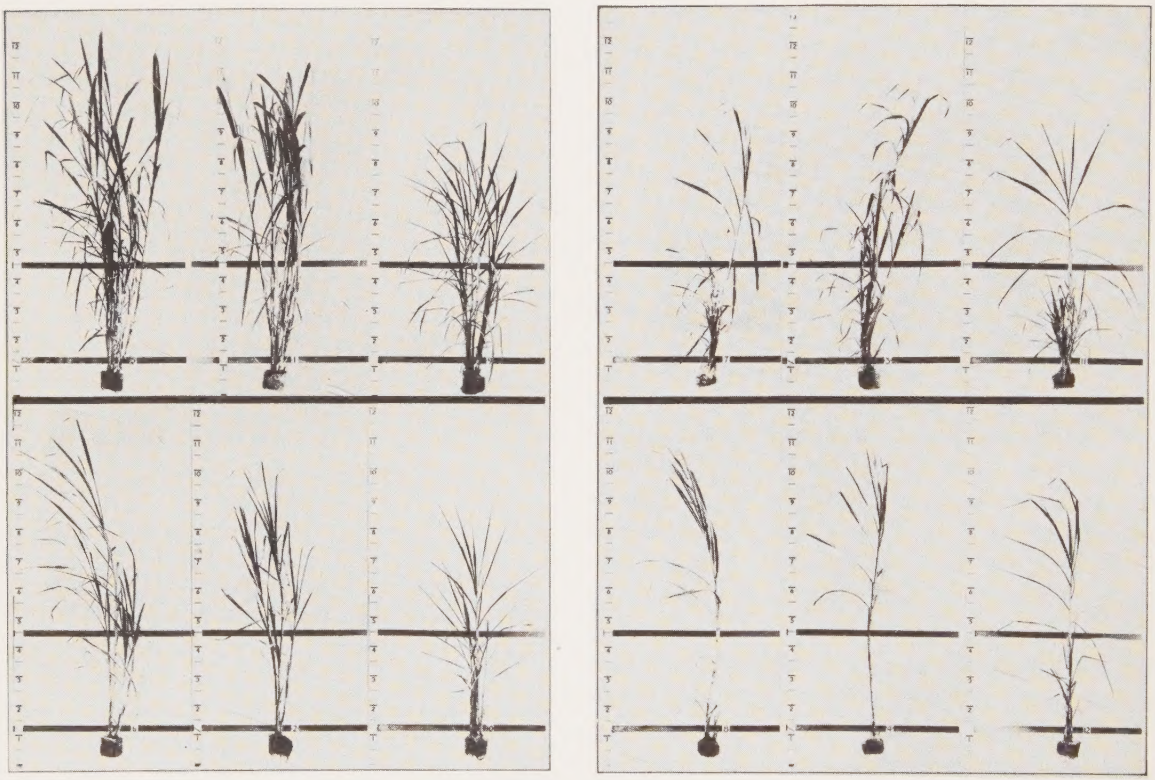


Figure 6. Variety 37-1933, eight months old, grown in controlled climate. Temperatures in both sections are: left, hot air (Makiki +9° F.); center, Makiki; right, cold air (Makiki −9° F.). In both sections, control in upper row is 32 ppm P; in lower row, low P (2 ppm P). Root temperatures are 72° F. for the six plants on the left; 62° F. for the six plants on right. All 12 plants received full sun.

Total P was determined at monthly intervals, using punch samples of Blade 4. At final harvest, 8-10 P was also determined. The results obtained for 8-10 P and leaf punch P taken at the final harvest are shown in Table 3, and were positively correlated.

8-10 P of controls ranged between 0.108 and 0.338, while that of the low P series ranged between 0.011 and 0.049 per cent dry weight. In both sets of plants, lowest values for 8-10 P were associated with best growing conditions, and highest values with poor growing conditions.

8-10 P of the low P series varied from well below to well above the critical range for P, although all plants of the low P series received exactly the same amount of P (2 ppm P changed every two weeks and used up in a few days).

These results suggest that when crop logging for P, the weather, soil temperature and amount of light should be considered. Need for P shows up first under good growing conditions.

Growth in both amounts of P, measured as fresh weight of tops (primaries plus suckers), was positively correlated with air temperature, root temperature, and sunshine. Suckers were more affected by both P and climate than were the primaries.

Absorption of P was measured by analysis of nutrient solutions and by the use of P32, and was also positively correlated with air and root temperatures and light. But climate affected growth more than absorption of P, for the lowest values of both 8-10 P and leaf punch P were associated with the best growing conditions.

Table 3. Climate and P Nutrition
(Final Harvest, July 6-8, 1959)

Series	Total P as % Dry Weight: Blade #4 Punches Control	1/16 P	8-10 Internodes Control	1/16 P
Hot 72 Sun	.269	.111	.108	.011
Hot 72 Shade	.298	.151	.174	.024
Hot 62 Sun	.408	.142	.228	.018
Hot 62 Shade	.558	.173	.305	.029
Makiki 72 Sun	.247	.141	.125	.016
Makiki 72 Shade	.372	.151	.219	.022
Makiki 62 Sun	.302	.165	.200	.022
Makiki 62 Shade	.434	.188	.270	.049
Cold 72 Sun	.321	.153	.199	.019
Cold 72 Shade	.452	.162	.331	.027
Cold 62 Sun	.531	.157	.303	.023
Cold 62 Shade	.672	.199	.338	.038

Primary Stalks. Composite samples of generally 4 stalks.
ppm P in nutrient solution: Control, 32; 1/16 P: 2.

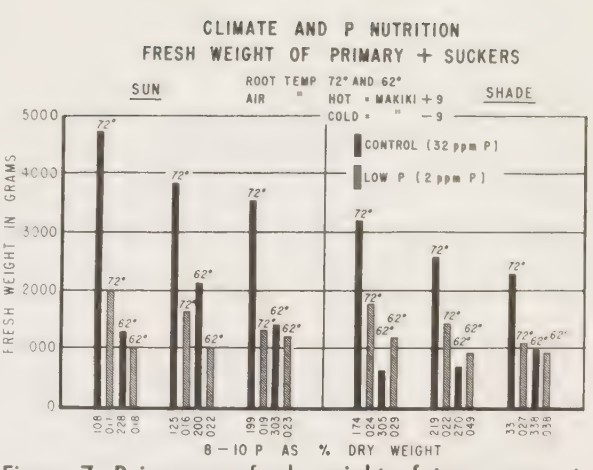


Figure 7. P increases fresh weight of tops more at high air and root temperatures and in full sun, than at lower air and root temperatures and in half shade.

From the data of Table 3, it is apparent that good growing conditions (high air temperature and high light) reduce the tissue phosphorus. There is a four-fold range of concentrations resulting from the conditions imposed. If .031 per cent P is accepted as the critical level for the 8-10 internodes, the plants in full sun and warm air are extremely deficient while those in half-light and cool air are well supplied with phosphorus.

It is of interest here that low root temperature retards growth more than the uptake of P, resulting in a higher P content of the tissues.

Figure 7 shows the combined effects of climate and phosphorus content on fresh weight yields. Figures 8 and 9 relate leaf punch P to stalk P. At low concentration, the P content of the 8-10 internodes increases about five times as fast as the leaf punch P. Figures 10 and 11 give the correlations between growth rate and 8-10 P for the controls and the deficient plants.

EARLY GROWTH RATE OF SUGAR CANE

This experiment was conducted at Waialua Agricultural Company, Ltd. in conjunction with the heavy nitrogen experiment. In addition to the regular field samples, an additional study was made of the growth characteristic of 37-1933 from a fifth ratoon cane in connection with the total number of joints as well as the total number of millable joints (#8 and below) produced for the 50-pound and 150-pound nitrogen per acre level.

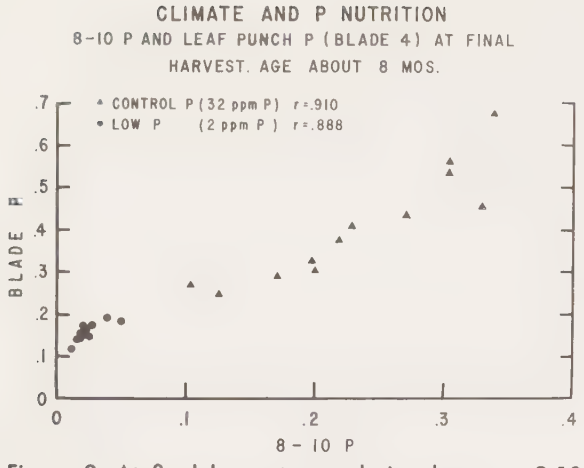

CLIMATE AND P NUTRITION
8-10 P AND LEAF PUNCH P (BLADE 4) AT FINAL HARVEST. AGE ABOUT 8 MOS.
▲ CONTROL P (32 ppm P) r=.910
• LOW P (2 ppm P) r=.888
BLADE P
8 - 10 P

Figure 8. At final harvest, correlation between 8-10 P and leaf punch P was positive.

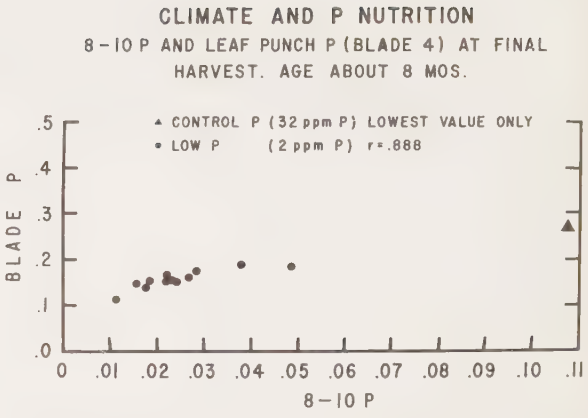

CLIMATE AND P NUTRITION
8-10 P AND LEAF PUNCH P (BLADE 4) AT FINAL HARVEST. AGE ABOUT 8 MOS.
▲ CONTROL P (32 ppm P) LOWEST VALUE ONLY
• LOW P (2 ppm P) r=.888
BLADE P
8-10 P

Figure 9. Relation between 8-10 P and leaf punch P in plants receiving only 2 ppm P. The data are the same as those in left part of Figure 8.

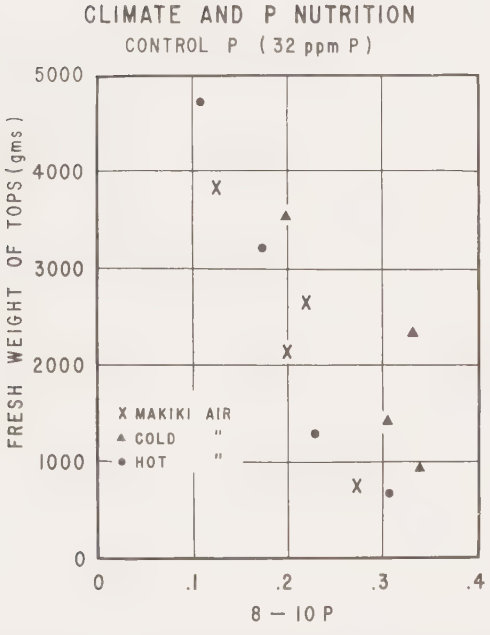


Figure 10. Rapid growth of tops uses the P rapidly, resulting in lower values for 8-10 P than in slower growing plants. 8-10 P of control plants (32 ppm P) ranged from 0.108 for series "Hot —72°—Sun" to 0.338 for series "Cold—62°—Shade." Correlation coefficient = —.827 (highly significant). % relationship = 68%.

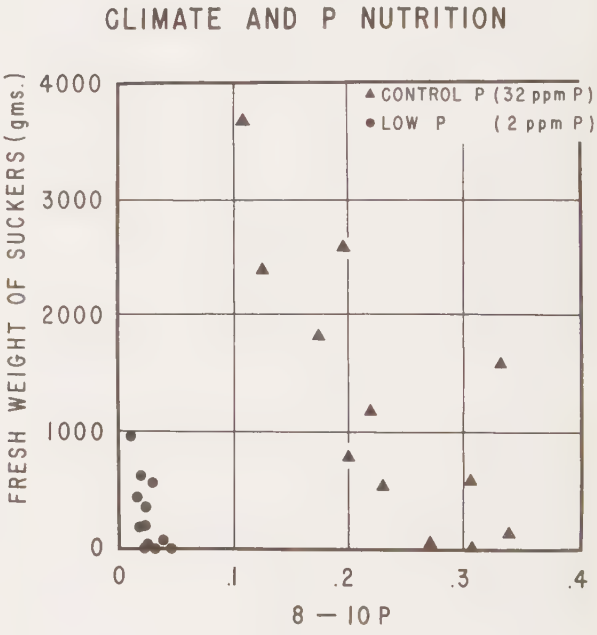


Figure 11. 8-10 P of primary stalk is increased when poor climatic conditions depress growth of suckers. Control: Correlation coefficient = —.762. Control: % relationship = 58%. Low P: Correlation coefficient = —.608. Low P: % relationship = 37%.

Results of this study are shown in Figure 12. As shown in this figure, higher level of nitrogen has definitely influenced the number of joints produced. The number of millable joints above ground first became apparent during the three to four month interval and progressively increased at the average rate of 2.4 and 2.3 joints per month, respectively, for 150 and 50 pounds of nitrogen per acre.

The primary purpose of this study was to answer the question of time lost after each harvest. It is evident that approximately three months go by before there is any new millable cane, a factor of great importance in seed plots. Each month after this three-month lag period adds about 2.4 new joints good for seed.

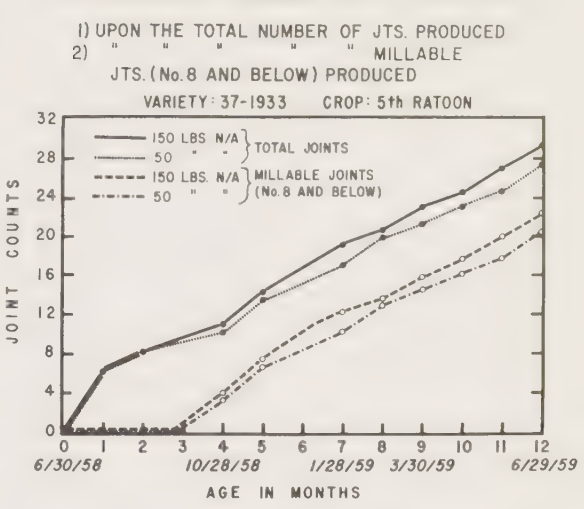

INFLUENCE OF AMOUNTS OF N APPLIED
1) UPON THE TOTAL NUMBER OF JTS. PRODUCED
2) " " " " " MILLABLE
JTS. (No. 8 AND BELOW) PRODUCED
VARIETY: 37-1933 CROP: 5th RATOON
150 LBS. N/A
50 " "
TOTAL JOINTS
150 LBS. N/A
50 " "
MILLABLE JOINTS (No. 8 AND BELOW)
JOINT COUNTS
0 4 8 12 16 20 24 28 32
0 1 2 3 4 5 6 7 8 9 10 11 12
6/30/58 10/28/58 1/28/59 3/30/59 6/29/59
AGE IN MONTHS

Figure 12. Higher nitrogen increases slightly the number of early millable joints above ground.

GIBBERELLIC ACID DOES NOT INCREASE YIELD OF SUGAR

Twelve plots of first ratoon 37-1933 were used to determine whether the application of gibberellic acid on a field scale would increase final yields at harvest. Two levels of G.A. were applied in irrigation water and in foliage spray and, to eliminate nitrogen as a limiting factor, each plot received the high levels of 700 or 900 pounds of nitrogen per acre.

The cane was harvested at 24 months. Each plot consisted of two outside and four inside lines. The cane stalks harvested from a six-foot segment of each line taken from the mid-section of the line were weighed and counted separately and the cane of the two center lines was further processed for pol ratio determinations. To eliminate differences of opinion by individual checkers as to what is dead cane at harvest, all dead and partly dead canes within the six-foot sections were counted, weighed and processed as part of the crop. Suckers with less than three dry leaf joints were discarded.

Repeated applications of G.A. did not increase cane or pol yields of 37-1933 at 24 months. In fact, plots that received the spray applications of G.A. gave lower yields than the controls, though this could be attributed not to G.A., but to mechanical injury of cane stalks in making the applications.

The over-all picture of the test indicates slightly higher yields from the 900-pound N plots over the 700-pound N plots. Averaged tons pol per acre differences were as follows:

	Outside Lines	Inside Lines
700 lbs. N	35.3	21.7
900 lbs. N	38.8	24.8

Detailed data for TCA, TPA and stalks per foot of line are given in Table 4.

PHOTOSYNTHESIS RATES OF LEAVES VARY

Twenty-two tests have been conducted with C14 for the purpose of perfecting a method of comparing

Table 4. Makiki G.A. Test—Harvest Yield Data

		Pol Ratio	Tons Cane/Acre Outside Lines	Tons Cane/Acre Inside Lines	Stalk/Foot Outside Lines	Stalk/Foot Inside Lines	Tons Pol/Acre Outside Lines	Tons Pol/Acre Inside Lines
Control:	700# N	7.90	276	162	16.20	8.72	34.9	20.5
	900# N	7.55	331	212	13.45	10.85	43.8	28.1
Low Soil:	GA 700# N	7.05	228	198	13.00	10.55	32.3	28.1
	GA 900# N	7.20	270	190	12.80	10.22	37.5	26.4
High Soil:	GA 700# N	7.90	291	184	15.00	8.98	36.8	23.3
	GA 900# N	7.60	276	214	14.45	11.45	36.3	28.2
Low Spray:	GA 700# N	8.15	272	138	14.50	8.08	33.4	16.9
	GA 900# N	7.95	328	152	16.90	8.80	41.2	19.1
High Spray:	GA 700# N	7.65	300	151	15.35	8.28	39.2	19.7
	GA 900# N	7.95	278	176	16.25	9.55	35.0	22.1

photosynthesis rates of leaves from different varieties or from plants grown under different conditions.

Best results are obtained if the blades are tested while attached to the plant. Injury to the leaves, even small bends in the midrib, may decrease the rate of incorporation of tracer carbon dioxide.

There is a gradient in rate of photosynthesis in a blade, with lower activity toward the base and apex, and maximum activity along the broad central section. Maximum activity was found in one test from 34 to 74 cm. from the dewlap, and in another test from 45 to 75 cm. from the dewlap. This part of the leaf was used in a comparison of all fully unrolled leaves on one stalk. The first four fully unrolled leaves did not differ significantly in photosynthetic rate. Maximum activity was found in the fifth to eighth leaves.

Leaf No. 7 from four stalks of different plants of Variety 37-1933 was then tested in the same way. Total counts per square centimeter under uniform conditions were: 145, 158, 164, 170. This variation is about the same as that found in adjacent leaves on one stalk.

An attempt was then made to apply this method in the climate houses. Except when a wooden beam cast a shadow on the leaf, in all other series the low P leaf did less photosynthesis than the high P leaf. Most striking result was obtained in the shade-grown plants, the photosynthetic ability being less than a third of the sun-grown plants.

MECHANISM OF PHOTOSYNTHESIS

Tests on the mechanism of photosynthesis and dark fixation of tracer carbon dioxide have given the following results:

Malic acid accounts for the highest percentage of counts fixed in the dark. Radioactive carbon of malic acid is transferred to sucrose in the light. Intermediates between dark-formed malic acid and light-formed sucrose include phosphoglyceric acid (PGA) and glucose-1-phosphate.

Highest total counts were obtained after five minutes "washing out" in $C_{12}O_2$ in the light. Washing out for one to three minutes in the light gave lower total counts than with no washing out, indicating the formation of a volatile intermediate.

Killing a dark-fixed leaf in alkaline alcohol increased the counts, some of which were lost on acidification.

Washing out in $C_{12}O_2$ for 10 minutes in the dark more than doubled dark fixation counts. These counts were mostly malic acid.

Formation of malic acid is greatly increased by light. With decreasing photosynthetic time, the per cent of total counts in malic acid increases while PGA decreases. By extrapolation to zero time, it appears that malic acid is formed before PGA.

ROOT TEMPERATURE AFFECTS ABSORPTION OF P32

P32 was fed to two low P plants (2 ppm P in the nutrient solution), the roots of which were held at 62° or 72°. Absorption and translocation were followed by direct Geiger counting at middle of a leaf and by counting successive leaf punches. As shown in Table 5, rates of absorption and translocation of P32 were two to three times faster at 72° than at 62° root temperature.

Roots of these plants were sampled at five minutes, 60 minutes, and 24 hours and analyzed for organic and inorganic phosphorus by the isobutanol method. Leaves also were analyzed. P32 after absorption was circulated in the plant in such a way that it became representative of the phosphorus composition of the plant. Since low root temperature decreased absorption but not circulation, effect on absorption must be on a primary step.

Formation of organic P in roots was less active at 62° than at 72°. Chromatographic studies indicated the P32 went first into sugar phosphates and nucleotides and then into residue and phospholipids. This process was decreased and slowed down by low root temperature.

Table 5. Root Temperature and Absorption of P32

Method	Temp.	Time of first Positive count	Distance	Rate cm/min.	Ratio 72°/62°
Direct counting	62°	38 min.	103 cm	2.7	1.7
	72°	32	144	4.5	
Leaf punch	62°	120	103	0.85	3.5
	72°	47	138	2.94	
	72°	55	166	3.02	

RADIOACTIVE ISOTOPES CHECK TRANSLOCATION OF K, Ca AND P

First use of radioactive potassium, K42, was in a test comparing three tracers: potassium, calcium, and phosphorus. These were fed to five plants as follows: #1, Ca45 + P32; #2, K42; #3, Ca45; #4, P32; and #5, Ca45 + K42.

Potassium moved the fastest. Direct Geiger counts showed potassium reached sheath #8 and top dewlap before the phosphorus. Counts of successive leaf punches gave the following rates for duplicate plants in centimeters per minute:

Isotope	Translocation Rate
K42	1.92
	Av. 2.08
	2.25
P32	1.22
	Av. 1.64
	2.07

Potassium averaged the faster rate, but the difference is not statistically significant.

Calcium was slower than the others, taking about 24 hours for detectable counts by the leaf punch method compared with less than two hours for potassium and phosphorus.

Plants harvested five to six hours after feeding had high K42 counts in the spindle. P32 counts in the same place and made the same way were low but definite. Ca45 counts of the spindle, made on Wiley Mill powder, were 0, compared with 400 for P32 counted the same way.

HEAVY NITROGEN (N15) HELPS IN FIELD STUDIES

This experiment was installed at Waialua to compare the rate of uptake of fertilizer when applied in equal amounts by two field methods: (1) in irrigation water, and (2) by injection with a standard field machine. By tagging the aqua ammonia with N15, it is possible to measure exactly how fast the fertilizer nitrogen is utilized as well as the total recovery of applied nitrogen by the crops.

Installed July 1, 1958, the experiment has progressed well during the past year and the final samples are now being sent to Minnesota for mass analysis. Leaf punch samples were taken at two-month intervals. Stools were removed at 2, 4, 7, 8, 10, and the final one at 12 months. The collected samples had been subdivided, dried and stored for analysis. Monthly trash collections were also made for N15 analysis.

Although the final conclusions must await completion of all analytical determinations, it can be stated here that the early analyses showed that the plants were absorbing the injected nitrogen more rapidly than that applied in irrigation water, a rather surprising result in view of the general broadcast over the stool which the latter method gives.

MOVEMENT AND STORAGE OF SUGARS IN SUGAR CANE

Dr. K. T. Glasziou, a physiologist with the Colonial Sugar Refining Co., Ltd., Australia, has worked closely with the Physiology and Biochemistry staff in the study of movement of radioactive sugars into and out of the storage tissue of the sugar-cane stalk. As leader of the project, he has combined methods of his own with those in use at the Makiki Station.

The results, preliminary as they are, have demonstrated that the chief sugar translocated from the leaf is sucrose. It has also been demonstrated that when a reducing sugar, glucose, is fed to these storage cells it is found in the cell only as sucrose.

By working with joints of different ages, it has been shown that the rates of storage of sucrose diminish as the joints become more mature.

The methods offer much promise in clarifying the details of sugar storage.

COMPARATIVE PHYSIOLOGY AND BIOCHEMISTRY OF VARIETIES OF SUGAR CANE

On September 26, 1957, 10 varieties of cane (39-3633, 32-8560, H-109, 49-5, 49-104, 37-1933, 38-2915, 39-7028, 44-3098, and 44-2772) were planted at Makiki and fertilized with two levels of nitrogen, namely 200 and 400 pounds per acre. Cane samples for growth measurements as well as for chemical analyses were taken at six, nine and 12 months of age. In taking samples, guard rows were avoided. A sample consisted of six representative stalks, three stalks each coming from Rows 2 and 5 of each plot.

The harvest for yield data will be completed at about 23 months of age. The ratoons will be continued for more detailed studies.

The following preliminary report gives the general average growth and composition picture for the 10 varieties as well as some differences noted between varieties.

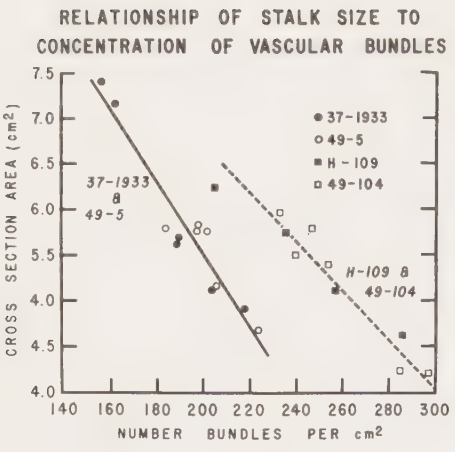


Figure 13.

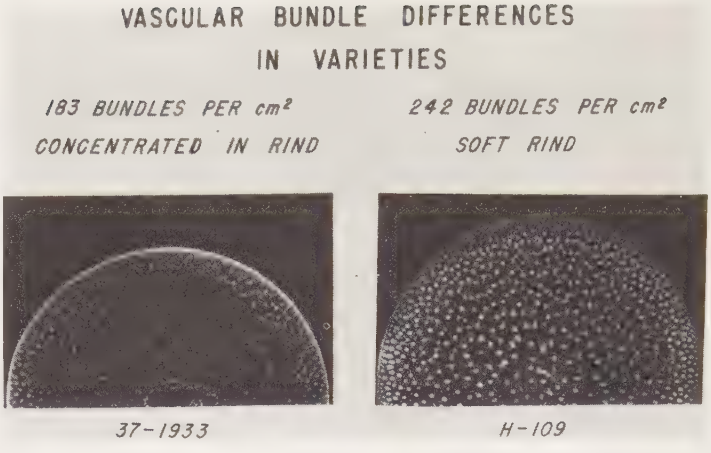


Figure 14.

Histological Investigations:

Figures 13 and 14 graphically show the relationships of vascular bundles to stalk size.

The number of bundles per joint is rather uniform. This results in a decrease in bundles per square centimeter as the joints increase in area.

Amino Acid Content of Varieties:

Analyses made to date do not indicate any striking varietal differences in amino acid content, nor do the results indicate that any one amino acid, or group of amino acids, can be used as an improved indicator of the plant's nitrogen.

Plant Weights:

Per plant weight for each of the 10 varieties ranked in the order: 32-8560, 44-2772, 37-1933, 39-3633, 49-104, 38-2915, 44-3098, H-109, 49-5, and 39-7028, at the 200 pounds N per acre level at six months. Range of weight was 1369 for the highest with 1160 for the lowest; the mean of all varieties at this level being 1268 grams. The variation for the 400 pounds N per acre level was considerably greater, with the heaviest noted for variety 44-2772, whose weight per plant was 1455 grams, and the least noted for variety 39-3633, weighing 1026 grams. The mean weight at this higher level of nitrogen was 1310 grams. This was slightly higher than that noted for the 200 pounds N per acre level. The ranking at this 400 pounds N per acre level was as follows: 44-2772, H-109, 37-1933, 49-5, 38-2915, 32-8560, 39-7028, 44-3098, 39-3633 and 49-104.

Per plant weight of the varieties at nine months and at the lower level of N ranked in the order: H-109, 38-2915, 32-8560, 39-3633, 37-1933, 39-7028, 49-104, 44-2772, 44-3098, and 49-5. The range of the values were considerably greater than the six-month harvest with the highest being 2928 and the lowest 1756, a spread of nearly 1200 grams. The mean of all varieties was 2138 grams. At the higher fertilizer N level, the ranking was again quite different, the spread in values from high to low being much narrower. The performance of 37-1933 at this level was striking in that it ranked first, with 39-3633 and H-109 running close second and third, respectively. The interesting point at this level of fertilization was that the range in weight was closer together than that noted at the 200 pounds N per acre level. The reversal in weight yield for H-109 and 38-2915 was noted as an exception. Otherwise, weights increased with increased nitrogen application.

At the 12-month harvest, more reversals in weight occurred. Of the 10 varieties, 39-3633, 32-8560, H-109, and 49-104 were heavier at the 200 pounds N per acre level than at the 400 pounds N per acre level. However, the mean of the 10 varieties at each nitrogen level was significantly in favor of the higher N level.

The effects of nitrogen and of age upon the amount of averaged green weight produced per plant are shown in Figure 15. Definitely, higher levels produced more green weight at time of each harvest. An interesting observation is the much larger amounts of green weight produced during the period six to nine months over nine to 12 months at the two levels of

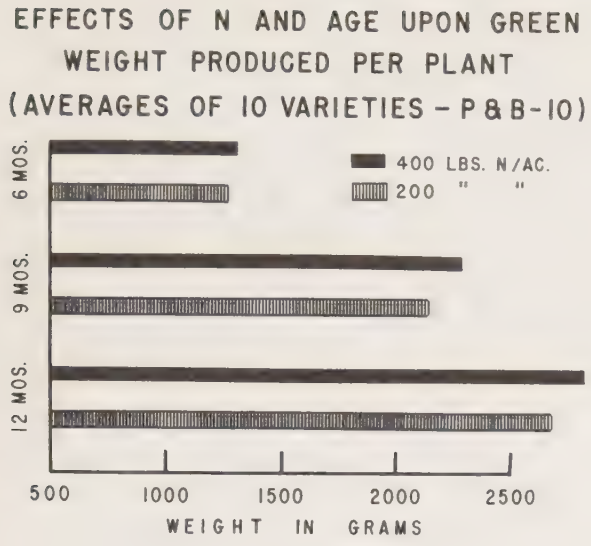


Figure 15.

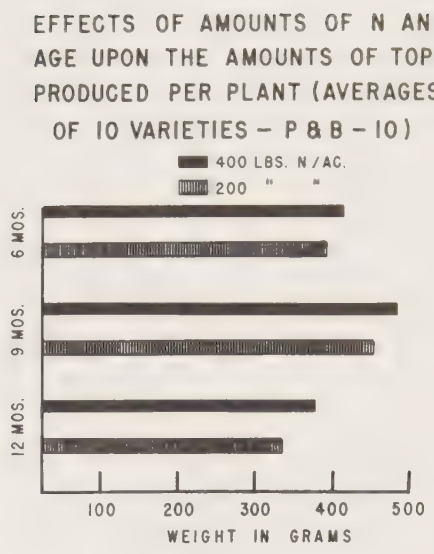


Figure 16.

N. This increased growth rate indicates that the period six to nine months is apparently in the boom stage of growth. Furthermore, the amount of green top material closely parallels the accelerated weight increase during this same period. This is clearly depicted in Figure 16. The effects of amounts of nitrogen are also shown: more tops for the higher nitrogen application.

Moisture Content:

The effects of the amounts of nitrogen on moisture content in the 3-6 blades, 3-6 sheaths, 8-10 blades, 8-10 sheaths, 8-10 stalks and basals of the cane plant at six, nine and 12 months of age are also definite; the greater nitrogen application resulted in higher moisture content. However, the moisture values of 4-5 and 6-7 joints at the two levels of N are, in nearly all varieties, of the same order of magnitude and, therefore, do not follow the higher nitrogen-higher moisture concept.

Total Nitrogen:

At the six-month harvest, the 400 pounds N per acre level actually had a higher percentage of nitrogen in nearly all parts of the plant analyzed. Exceptions were in 8-10 internode and basals of variety 39-3633 which showed lower per cent TN at the 400 pounds N per acre than at the 200 pounds N per acre level.

At nine months, the exceptions noted for variety 39-3633 have disappeared, but in its stead, lower values were noted for basal TN of variety 44-3098. Apart from this deviation, higher or equal TN values were obtained for all plant parts of each variety from the larger amounts of nitrogen.

At 12-month harvest, variety 44-2772 and 49-104 analyzed lower per cent TN for the 400 pounds N per acre fertilized plot and the 200 pounds N per acre in nearly all the plant parts. Other varieties were consistent in following the trend of higher per cent TN for higher nitrogen fertilization.

The per cent TN composition in all parts of the cane plant for each variety progressively decreased with age.

Figure 17 shows the averaged nitrogen composition in various parts of a cane plant fertilized with 400 and 200 pounds N per acre at six, nine and 12 months of age. The tissues richest in nitrogen are the young blades, sheaths, and 4-5 cane joints, and the least rich are the older leaves and the basal joints of the plant. The figure also shows that plants which received larger amounts of nitrogen are consistently higher in per cent TN.

At age six months and at 200 pounds N per acre level, four varieties showed lower 8-10 TN values than the tentative critical level of .23 per cent. These four were 32-8560, H-109, 49-5 and 49-104. However, at the 400 pounds N per acre, values were all above the set critical level.

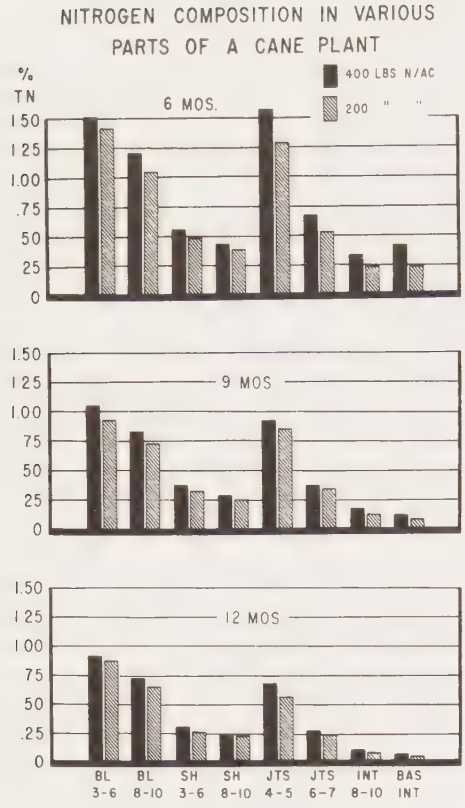


Figure 17.

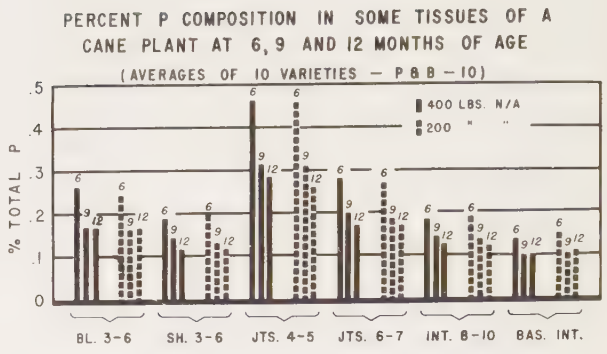

PERCENT P COMPOSITION IN SOME TISSUES OF A CANE PLANT AT 6, 9 AND 12 MONTHS OF AGE
(AVERAGES OF 10 VARIETIES — P & B — 10)
% TOTAL P
400 LBS. N/A
200 " "
BL. 3-6
SH. 3-6
JTS. 4-5
JTS. 6-7
INT. 8-10
BAS. INT.

Figure 18.

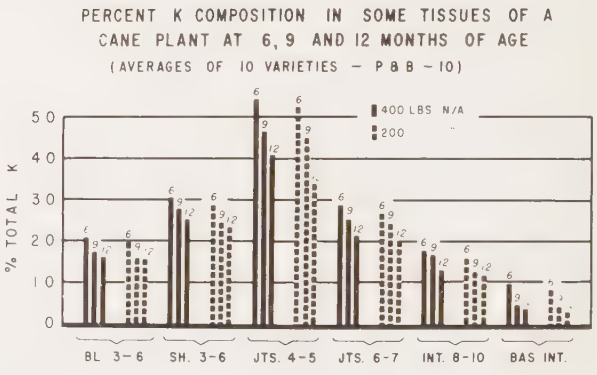

PERCENT K COMPOSITION IN SOME TISSUES OF A CANE PLANT AT 6, 9 AND 12 MONTHS OF AGE
(AVERAGES OF 10 VARIETIES — P & B — 10)
% TOTAL K
400 LBS N/A
200 "
BL 3-6
SH. 3-6
JTS. 4-5
JTS. 6-7
INT. 8-10
BAS INT.

Figure 19.

At age nine months, all 8-10 TN values were much below the .23 per cent level. Similarly, nearly all varieties at the 400 pounds N per acre level showed values below the critical amount with the exception of varieties H-109 and 44-3098, which had values above .23 per cent.

At age 12 months, 8-10 TN analyses for all varieties and for the 200 and 400 pounds N per acre levels were all below the set critical level.

Looking at leaf punch, 8-10 and basal total nitrogen values at age nine months for all the 10 varieties, it is clear that differences between varieties in their nitrogen composition are definite. Larger amounts of nitrogen fertilization gave higher percentages of nitrogen in all these tissues. Of the 10 varieties, 39-7028 failed to show the effects of higher nitrogen in leaf punches and basal internodes. Actually, the basal values showed a reversal of the expected results in that per cent basal TN of the 200 pounds N per acre was higher than that of the 400 pounds

Table 6. Varietal Differences in Nitrogen Composition
(P & B 10 at 9 months)

Plant Part	N Fert. Level # N/A	39-3633	32-8560	H-109	49-5	49-104	37-1933	38-2915	39-7028	44-3098	44-2772
3-6	200	1.36	1.35	1.50	1.25	1.25	1.48	1.50	1.61	1.67	1.28
Leaf Punches	400	1.84	1.49	2.03	1.61	1.43	1.64	1.74	1.61	1.78	1.50
8-10	200	.121	.099	.150	.115	.098	.114	.126	.131	.135	.097
	400	.205	.119	.297	.173	.123	.136	.167	.161	.266	.127
Basal	200	.083	.073	.062	.067	.074	.092	.076	.098	.079	.071
	400	.229	.121	.127	.137	.084	.102	.148	.089	.118	.098

Note: Values expressed as percent TN, Dry Wt. Basis.

N per acre level. These analytical values are summarized in Table 6.

Potassium:

Shown in Figure 18 is the potassium composition in some tissues of a cane plant fertilized with 400 and 200 pounds N per acre at six, nine and 12 months of age. Joints 4-5 were highest in per cent K and least for the oldest basal internodes. The suppression of K by nitrogen is not apparent. The tentative K index for 3-6 sheaths or 8-10 internodes does not reveal a deficiency of potassium at the two levels of nitrogen applied.

Phosphorus:

Figure 19 shows the averaged (10 varieties) phosphorus composition of some of the different parts of the cane plant fertilized with 400 and 200 pounds N per acre at six, nine and 12 months. As in the potassium composition, the younger tissues were richest in per cent P and the older tissues poorest. The suppression of P by nitrogen was not shown. On the basis of established sheath 3-6 P and 8-10 P indexes, deficiency of phosphorus in either tissue was not indicated at the 400 or 200 pounds N per acre level at the ages of harvest.

DISEASES

DISEASE RESISTANCE TRIALS IN FIJI

The cooperative program with the Colonial Sugar Refining Company, Ltd., initiated in 1951 for testing Hawaiian-grown varieties against Fiji disease and downy mildew in Fiji, was placed under the supervision of D. R. Strong, Chief Field Officer, CSR, in 1959 following the departure of P. B. Hutchinson, who was formerly in charge of the project.

In May 1959, 28 Hawaiian varieties were sent to Fiji and were planted in the Bekana quarantine area. These varieties will be included in the trials following their release from quarantine in 1960.

The results from the one downy mildew disease trial which included 60 Hawaiian canes, were satisfactory; the excessively high incidence of the disease in the second trial, which included 18 Hawaiian varieties, makes it necessary to retest these varieties.

The best results from the Fiji disease trials were those at Labasa, followed by those at Murisara and Lautoka.

The reaction of some of the more promising varieties to the two diseases are given below. The symbols in parentheses represent a previous rating.

	FD	DM
39-5803	+(=+)	=(=+)
7028	=+(=+)	=+(++)
45-2608	=(=+)	=(=+)
46-564	+(+)	=+(++)
48-4605	—	=+
48-4899	=+	—
50-2542	+	=+
7209	—	——
51-8194	+	+
52-123	—	——

NEW VARIETIES RELEASED AT MOLOKAI QUARANTINE

During the past year, the 18 varieties imported as cuttings through the USDA in 1956, and 143 varieties grown from seed imported from New Guinea by Dr. J. N. Warner in 1957, were released from quarantine and sent to the Kailua Substation by the Quarantine Committee. Nineteen varieties imported from the USDA in 1957 were released to the quarantine field at Mapulehu, and 30 varieties imported in November 1958 were planted in the quarantine house.

The cane varieties under greenhouse and field quarantine were inspected periodically and were found free from symptoms of diseases foreign to Hawaii.

1959 DISEASE PICTURE

General inspections of commercial plantings of sugar-cane varieties were made on all plantations to assess the prevalence of cane diseases.

Red rot disease was still causing considerable damage to the variety 38-2915 in a few areas; the acreage of this variety has been substantially reduced since the first outbreak of this disease in 1954. Varietal resistance tests have been conducted to determine the reaction of varieties to the disease.

Chlorotic streak was found to be quite widespread in the heavy rainfall areas on Hawaii; it was found on one plantation where it had not previously been reported.

Leaf scald disease was noted in 44-3098 fields approaching maturity on the Hilo Coast, but was causing only minor losses.

Ratoon stunting disease was found in a localized area of a commercial planting of 37-1933 on Kauai. Occasional symptoms were noted on seedlings during field inspections. It is important that new varieties being spread on plantations are free of the disease; this is best accomplished by establishing disease-free nurseries with long hot-water-treated (50°C. for 2 hours) cuttings and by sterilizing knives used for cutting seed in the nurseries. These procedures minimize the danger of spreading the disease. It is also important to keep the seed areas free from volunteer stools which may be diseased.

Pineapple disease was responsible for some damage to sugar-cane cuttings and caused poor germination in a few instances. The treatment of cuttings with PMA is recommended where this disease may be a factor in reducing germination.

Sour rot was causing considerable damage in fields which had suffered severely from drought during the 1958 strike and which were dried off for long periods because of insufficient irrigation water.

RED ROT RESISTANCE TEST INSTALLED AT LIHUE

The seriousness of red rot disease to the sugar industry has been discussed in various reports, and it was pointed out that the ultimate control measure of the disease will be the replacement of susceptible varieties with resistant ones; periodic testing of varieties must be continued since new strains of the organism may develop and make for susceptibility in a variety which was once resistant.

This test installed in May 1958 at the Lihue Variety Station to determine the reaction of commercial and new promising varieties to red rot was harvested in March 1959. The test varieties and the susceptible check variety, 38-2915, were inoculated with the red rot organism (*Physalospora tucumanensis*) according to the method described previously. The reaction of each variety to red rot as determined in this test is listed below. Varieties marked with an asterisk were not graded due to severe rat damage.

39-5803=+
3633+ to ++
41-1045+
46-3037+ to ++
47-1923=+
2976+
48-3836*
4046+
4646+
49-612 *
823 +
3533=+ to +
3698=+
3945+
4060+
50-2010+
2542=+
50-2895= to =+
3601+
4107+
7209+
51-760 +
2279+
3521+
4187=+
4212=+
4448=+ to +
4768= to =—
5017= to =+
5064+
6238+
8194++
8422+
52-123 =+
52-2015+
2020=
3678+
4511+
5002=— to —
53-779 +
1447+
1494=+ to +
2059*
54-101 =+ to +
182 +
366 =+ to +
54-1356+ to ++
4023=+
38-2915(X)----

This test is being ratooned and the varieties will again be inoculated to determine their reaction to the disease at a different time of the year.

RATOON STUNTING DISEASE CONTINUES AS A PROBLEM

A varietal test of the resistance to ratoon stunting disease of 20 commercial and promising varieties showed a significant decrease in yield for diseased, in comparison with healthy, cane when harvested at 19 months of age. The average yields for diseased and healthy canes for all varieties are as follows:

Treatment	TCA	PR	TPA
Healthy	140.4	9.2	15.1
Diseased	127.8	9.5	13.1
LSD	9.0	....	1.1

In this test, the variability in yields, combined with the minimum number of replications, made it impossible to measure the differences in resistance and susceptibility of the varieties. Two additional tests were installed during 1959 in which a longer irrigation interval will be used to induce more stress in the growth of cane, in order to obtain greater differences in the yields between the healthy and diseased plots. The varieties in these tests are:

39-3633
5803
41-1045
3340
44-2772
45-2860
49-5
134
3404
3533
50-723
7209
51-3049

RESEARCH ON PINEAPPLE DISEASE CONTROL CONTINUES

Reduced germination resulting from pineapple disease, caused by *Ceratocystis paradoxa,* was reported mainly from areas where the cuttings had not been treated with PMA. The use of good quality seed cane which germinates quickly after planting helps to reduce the mortality of buds from this disease.

Twelve new fungicides were tested in the laboratory, and eight were tested on cuttings in the field; none of these fungicides was superior to PMA.

An experiment to determine the optimum number of nodes per seedpiece, where rotting from pineapple disease may be expected, showed an advantage for four or more buds per cutting over those with two or three buds. Four-eye cuttings increase the chances for one of the center buds to escape infection and mechanical injury. If the center bud of a three-eye cutting is injured, it no longer has an advantage over a two-eye seedpiece.

A number of chemicals furnished by the Chemistry Department were tested for sealing the freshly cut ends of cuttings to prevent cracking, thereby checking the entry of rot-producing organisms; none of the materials tested was completely satisfactory.

VARIETIES BEING CHECKED FOR RESISTANCE TO LEAF SCALD DISEASE

The most effective control of leaf scald disease, caused by *Xanthomonas abilineans,* is the use of resistant varieties. A test to determine the reaction of 34 commercial and promising new varieties was installed in June 1959, at Olaa Sugar Company, Ltd.

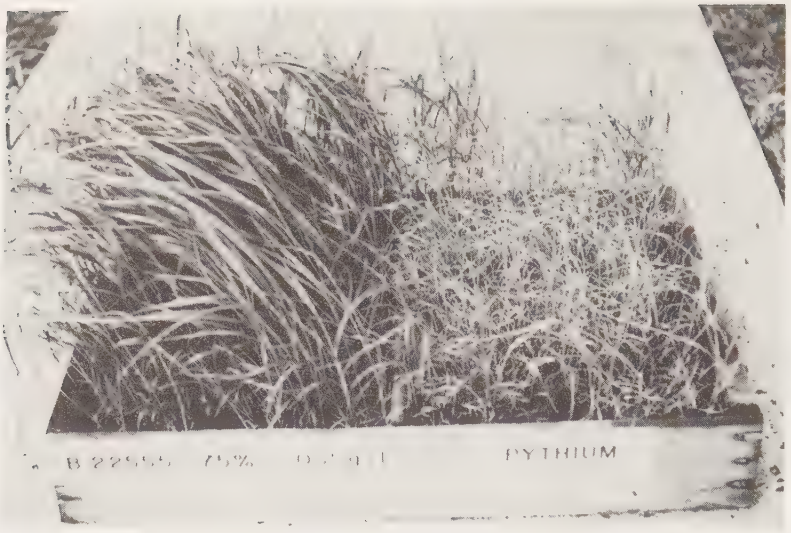


Figure 20. The left half of a *Pythium*-inoculated flat of seedlings was treated with Bayer 22555 (.2 g per flat of 75 per cent active); the right half was untreated. Note excellent control of root rot treatment.

Replicated plots of each variety were planted with cuttings inoculated with the leaf scald organism. The varieties in this test, including the susceptible check variety 28-4291, are listed:

39-5803	46-564	49-5	50-723	50-7464	52-246
7028	3037	104	2542	51-760	53-1447
41-3340	48-546	118	4508	4336	54-366
44-2772	4178	612	6062	8194	775
3098	4605	3404	6877	8422	28-4291(X)
45-2860	4899	3533	7209	52-123	

PYTHIUM ROOT ROT UNDERGOES INTENSIVE RESEARCH

The fungicide, Bayer 22555 (p-Dimethylaminobenzenediazo sodium sulfonate), supplied by Chemagro Corporation, continued to look promising for the control of *Pythium* root rot of sugar-cane seedlings in flats (Figure 20). During the 1960 seedling season, it is proposed to replace Captan with this material for preventing and controlling the disease at the rate of .2 g per flat of the 70 per cent active fungicide, applied at weekly intervals. A flat contains approximately 1.9 square feet of surface soil with a depth of four inches.

The results of several greenhouse pot tests indicate that B 22555 is quite effective for controlling *Pythium* root rot of sugar cane (37-1933, Figures 21 and 22) when added to the soil in two separate applications of 133 pounds per acre at biweekly intervals. The fungicide SD 4741 (a Shell Development Company product) did not control *Pythium* root rot and was found to be slightly toxic to sugar cane at the rates used.

B 22555 appears to have a selective nematocidal effect, especially against the stubby-root nematode (*Trichodorus* sp.) at 133 pounds per acre. Further studies will be conducted against nematodes using lower rates of the fungicide as recommended by its manufacturer.

Field observational tests with B 22555 have been installed at the Pathology Plot, Waipio Substation and the Oahu Sugar Company, Ltd.

EFFECTS OF NEMATODES AND FUNGI, SINGLY AND IN COMBINATION, ON THE GROWTH OF SUGAR CANE

Several pot tests were designed and installed by Dr. Walter J. Apt, Associate Nematologist, USDA, Western Washington Experiment Station, Puyallup, Washington, and members of the Pathology Staff, to study the pathogenicity of relatively pure populations of a single species of four genera of nematodes. The nematodes were tested alone and in combination with the root-rot fungus, *Pythium graminicolum,* and a fungus, *Fusarium oxysporum,* which was originally isolated from sugar-cane roots.

Figure 21. The growth response of 37-1933 to treatment of *Pythium*-inoculated soils with B 22555 is shown by the three pots at the right. Poor growth in *Pythium*-inoculated pots receiving no fungicide is shown in the three pots at the left.

Results indicate that the spiral nematode, *Helicotylenchus nanus* (Figures 23 and 24), the root-knot nematode, *Meloidogyne incognita* variety *acrita* (Figures 25 and 26), and the stubby-root nematode, *Trichodorus* sp., are pathogenic to sugar cane when seedlings and/or one-eye cuttings of the variety 37-1933 are used as test plants. The dagger nematode, *Xiphinema* sp., did not reduce cane growth at the population levels tested.

In the case of the spiral nematode, an inverse relationship was noticed between the population levels of the nematode and root and top growth.

The root-rot fungus, *Pythium graminicolum,* caused a significant reduction in growth of both cane seedlings and the variety 37-1933.

The combination of root-rot fungus and the spiral nematode or root-knot nematode did not reduce top or root growth appreciably more than did either agent alone. There was no clear-cut evidence that a nematode-fungus complex existed between the spiral or root-knot nematode and root-rot fungus.

Fusarium oxysporum alone caused a highly significant increase in top growth of sugar-cane seedlings, but no significant increase in root growth.

The combination of the root-knot nematode and *Fusarium oxysporum* resulted in a significant reduction in root growth but not in top growth. The root-knot nematode alone caused a significant reduction in both root and top growth. The lack of a depressing

Figure 22. Note the differences in root development of 37-1933 in *Pythium*-inoculated soils with (right) and without (left) the addition of B 22555.

Figure 23. Showing the effects of *Helicotylenchus nanus* (spiral nematode) at 10,000 nemas per gallon container (H-3) and *Pythium graminicolum* (P), alone and in combination (H-3+P), on the top growth of variety 37-1933, as compared to growth in the fumigated check (F-X) soil. Note the depressed growth in the unfumigated check (X) soil.

Figure 25. Showing the effects of the root-knot nematode, *Meloidogyne incognita* var. *acrita* (M), and *Pythium graminicolum* (P), alone and in combination, on the top growth of sugar-cane seedlings in comparison with growth in the fumigated check (F-X) soil. Note also differences in growth between plants in the unfumigated check (X) and fumigated check (F-X) soils.

Figure 24. Showing the effects of *Helicotylenchus nanus* (spiral nematode) at 10,000 nemas per gallon container (H-3) and *Pythium graminicolum* (P), alone and in combination (H-3+P), on the root growth of Variety 37-1933, as compared to growth in the fumigated check (F-X) soil. Note the poor root development in the unfumigated check (X) soil.

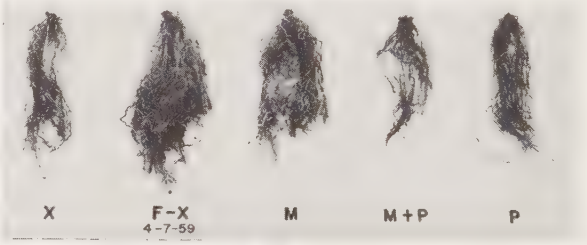


Figure 26. Showing the effects of the root-knot nematode, *Meloidogyne incognita* var. *acrita* (M) and *Pythium graminicolum* (P), alone and in combination (M+P), on the development of roots of sugar-cane seedlings, in comparison with roots from the fumigated check (F-X) soil. Note the poor root development in the unfumigated check (X) soil.

effect on top growth by the root-knot nematode in the presence of *Fusarium oxysporum* may be due to the stimulating effect of *Fusarium* upon top growth.

In every case, a better top and root development of cane was noticed in the methyl bromide-fumigated check soils (F-X) than in the unfumigated check soils (X). All nematode and fungi additions were made to soils fumigated with methyl bromide prior to the installation of the experiment.

The investigations conducted by Dr. Apt were carried out under the research grant made available to this Station by the Shell Chemical Company and were, in part, a continuation of the studies initiated by Dr. Harold J. Jensen while at this Station in 1957-1958. Arrangements have been made (September 1959) with the University of Hawaii for Dr. O. V. Holtzmann to continue on a part-time basis with some of Dr. Apt's studies and to undertake new investigations of the part nematodes are playing in the yield decline of sugar-cane varieties.

FACTORY

CANE DIFFUSION PILOT PLANT IN OPERATION

The cane diffusion pilot plant installed at the Kekaha Sugar Company, Ltd. factory went into operation on March 11 (Figure 27). From then until August 21, 10,388 tons of cane were processed. During this period, most of the mechanical problems were solved and preliminary operational data on the various variables were obtained.

Cane Preparation: Preparation of cane for diffusion has been obtained by a two-stage method using first the Rietz Prebreaker machine followed by a Rietz Disintegrator. The Prebreaker has good feed characteristics and will handle all lengths of cane, reducing it to a satisfactory size with respect to length. Approximately 25 per cent is still in chunks too large for diffusion. The material from the Prebreaker, therefore, is fed dry into the disintegrator, a vertical swing hammer machine which reduces the remainder to the fine state necessary for diffusion. Capacity of the present equipment approaches 20 tons per hour.

Preliminary tests have also been made with a small Gruendler shredder, and it is probable that this sort of a machine can also be used in the first stage of preparation although shredding tends to give too long material of too low density.

Diffuser Operation: The Silver DDS diffuser, set at a slope of 2° 21′ and equipped with continuous scrolls and inclined bagasse discharge scrolls, handles the prepared cane well, also at a rate close to 20 tons per hour.

It is essential to efficient work in the diffuser that it be completely filled with cane at all times; otherwise, blank spaces result in channeling, excess water usage and poor capacity. This has been difficult to maintain due to stoppages in the cane supply from the cleaning plant. With the installation of a chopped cane storage hopper, with a five-minute cane supply capacity, the situation has been improved, but stops of longer duration interrupt the diffuser operation. The major effect of these is to cause an increase in dilution.

Investigational Results: During July and August when most of the data were collected, the plant averaged 13.2 tons of cane per hour, bagasse pol averaged 0.55, and extraction 94.5. These averages, however,

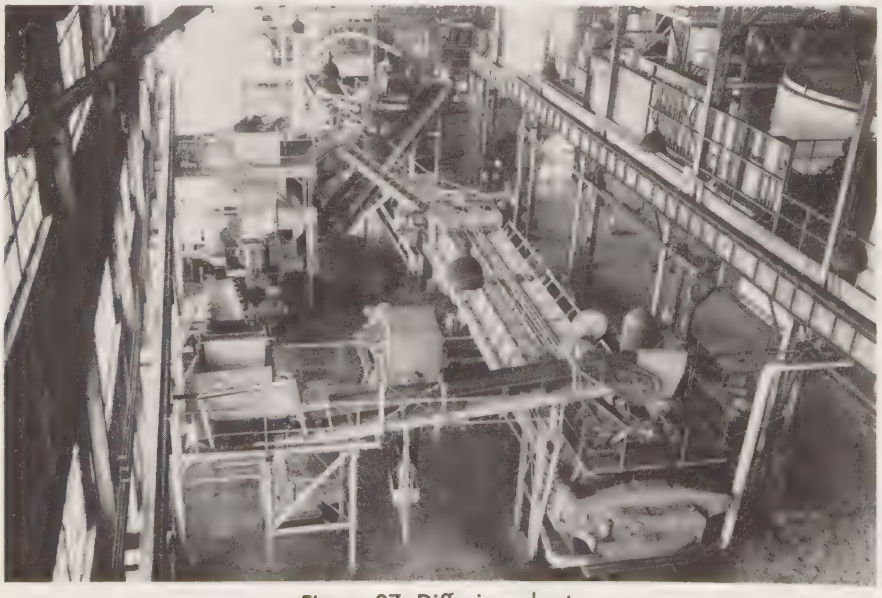


Figure 27. Diffusion plant.

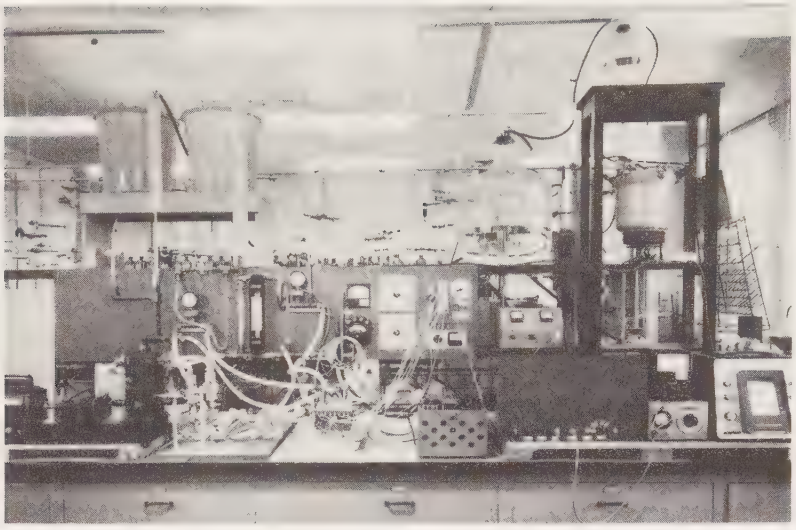


Figure 28. Laboratory Ionics unit.

are not indicative of optimum operation. The highest processing rate for a period was 17.8 tons per hour. The longest continuous run was for a three-day period during which the rate was 16.1 tons cane per hour. The best extraction for a daily period during the year was 97.0. Dilution has been high for the most part due to discontinuity of operation. During good runs, as for example the three-day period mentioned above, dilution on Absolute Juice was 40 per cent.

The first phase of the investigation, which involved getting the plant running and studying the preparation and diffusion of cane without dewatering the bagasse, is complete. The second phase, in which the bagasse will be dewatered in a screw press, will start in September. This will give the information necessary relative to extraction and dilution. Calculations indicate that the average extraction should rise above 98 and dilution should drop. Also, the effect of other factors such as temperature remains to be determined.

DEVELOPMENT OF GAMMA-RAY WEIGHING DEVICE FOR BAGASSE COMPLETED

The gamma-ray weighing device for bagasse has been developed to a point of sufficient accuracy and stability to be useful for the continuous weighing of bagasse in the factory. The experimental instrument was placed in operation at the beginning of the grinding season at Ewa Plantation Company and was run, essentially without interruption, until grinding was completed on July 31. During this time, a number of calibration points were obtained in cooperation with the Physiology and Biochemistry Department and a statistical analysis of the results was made.

These studies showed a standard error of an individual 10-second sample of $\pm$ 1.8 tons bagasse per hour. This is $\pm$ 4.4 per cent of the average flow rate. The error in total weight of bagasse measured over an hour's time would be considerably less—in the order of $\pm$ 0.23 per cent. This decrease is due to the fact that the errors in individual reading are random and tend to cancel each other out when many readings are involved.

It is believed that in routine operation the accuracy of hourly weights should be of the order of $\pm$ 1.0 per cent.

POLYELECTROLYTE SEPARAN AP-30 MOST EFFECTIVE MATERIAL IN CLARIFICATION

Tests at Hutchinson Sugar Company, Ltd. and HC&S have shown that Separan AP-30 is the most effective material in increasing the settling rate and improving the clarity of limed mixed juice. Separan AP-30 is the commercially manufactured version of the locally modified ET-81 which has been used for some time in many factories.

At Hutchinson, treatment with 2 ppm of AP-30

increased the settling rate of limed and heated juice five to 10 times. The effect on clarity was variable, there being considerable improvement sometimes, and other times none.

At HC&S in semi-plant tests, AP-30 gave approximately the same settling rate as ET-81, both of which were substantially faster than for the untreated juice. The clarity of the juice treated with AP-30 was better than with ET-81. The plant tests at HC&S also demonstrated that the best clarity is obtained when the polyelectrolyte is added at the flash tank of the clarifier.

CONTROL INSTRUMENTATION FOR ELECTRIC MEMBRANE DEMINERALIZATION PROCESS

Last year the investigation of the demineralization of juices with the Ionics electric membrane pilot unit installed at HC&S demonstrated that buildup of electrical resistance in the anion membranes could be minimized by operation below the polarization potential. As this potential varies with the composition of juice, it became essential to develop instrumental control.

In order to do this, a small laboratory unit has been set up at the Experiment Station (Figure 28). This unit is being used to develop a technique for detecting the polarization point and instrumentation to control the operation of the unit below this point.

DIGITAL COMPUTER USED ON ANNUAL FACTORY REPORT

During the year, a substantial beginning was made in carrying out computations for the Annual Factory Report on an IBM 610 digital computer. Tables 2 and 3 of the 1958 report were computed for the most part on this machine. It is estimated that Tables 2, 3 and 5 can be computed in 22.5 hours with this machine compared with 240 hours with a desk calculator.

The 1959 Factory Report will be calculated by this method.

FROTH CLARIFICATION OF SYRUP AND MOLASSES NOT EFFECTIVE

Laboratory tests on the froth clarification of syrup and molasses showed that this procedure is not effective in improving the quality of the material. This processing, although sometimes increasing the filterability, always gave an increase in color. This apparently is due to the action of heat and aeration.

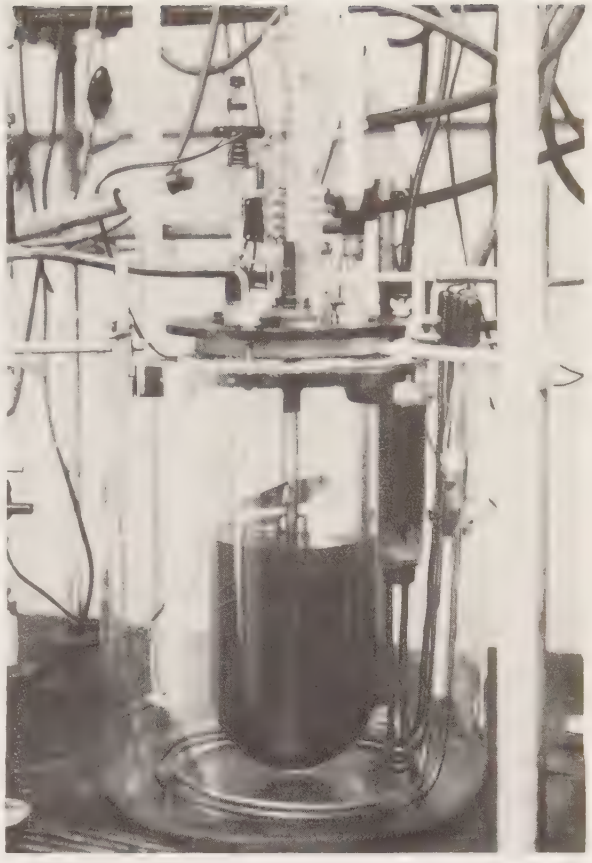


Figure 29. Laboratory vacuum pan.

EFFECT OF VARIOUS SUBSTANCES ON THE RATE OF SUCROSE CRYSTALLIZATION

The investigation of the rates of crystallization of sucrose in the presence of various substances has continued. During the year, the work was extended to five new compounds:

Lime: This caused a decrease in crystallization rate of five to six per cent. The predominant effect may be the action of lime on the pH of the sucrose solution.

Potassium Carbonate and Sodium Carbonate: Both of these compounds have a strong retarding effect on the rate of crystallization. In three per cent concentration the rate is decreased by 85 to 86 per cent. Here again, the pH effect may be influencing.

Hodag CB-6: This is a commercial surface-active agent. It was found to have no appreciable effect on the crystallization rate.

Raffinose: Although raffinose is not found in cane, it was desirable to determine the effect of such a trisaccharide. It was found to decrease the crystalliza-

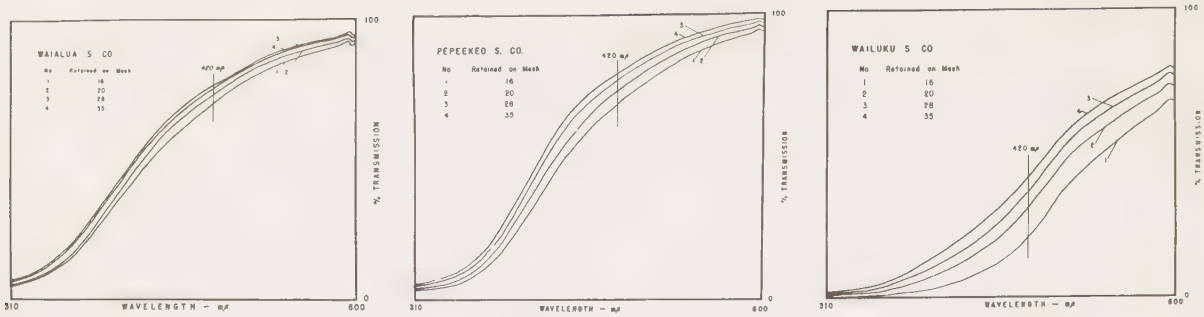


Figure 30. Transmittancy curves according to grain size for sugar from single strike from three plantations: Waialua, Pepeekeo and Wailuku.

tion rate by 23 per cent at a concentration of 0.18 per cent.

Pectic Acid: Pectic acid was found to have only a very slight retarding effect on the crystallization rate.

APPARATUS BUILT FOR STUDYING THE CRYSTALLIZATION RATE IN NATURAL SYRUPS AND MOLASSES

All of the recent work on crystallization rate at the Experiment Station has been done with pure sucrose solutions to which various substances have been added. With the data from these studies, it now becomes important to extend the work to natural syrups and molasses. In order to do this, a new technique must be developed.

An apparatus, which is essentially a miniature vacuum pan, has been built (Figure 29). This enables the crystallization under conditions analogous to those obtaining in a commercial vacuum pan. This will be used to determine the effect of physical factors such as rate of growth, temperature, and crystal size, as well as effect of various constituents on the quality of sugar crystal resulting.

RELATIONSHIP BETWEEN CRYSTAL SIZE AND CRYSTAL QUALITY

Spectrophotometric measurements in the visible region have shown that color decreased in every case with decreasing size for crystals from the same strike from the same plantation. This is illustrated in Figure 30 and supports previous findings. The similarity in the transmittancy curves suggests that the difference in color between the various size crystals was due to the quantity of colored substances present rather than to their nature. This study was made possible by the use of the new Beckman DK-2 ratio spectrophotometer.

During the year, daily composite samples of sugar from Lihue have been analyzed for quality. The results to date show a highly significant correlation between crystal size and crystal color. The statistical analysis shows that approximately 40 per cent of the variation in color can be attributable to size.

There was a less significant correlation between crystal size and filterability, but a highly significant correlation between crystal color and filterability. These results confirm the laboratory findings and give a good indication of the effect of grain size on quality in commercial boiling.

DEVELOPMENT OF SUGAR COLOR DURING PROCESSING

Two types of highly colored substances having their origin in reducing sugars have been shown to be responsible for a proportion of the color in the raw sugar crystal. These are thermal decomposition products and melanoidins from the reaction between glucose and degradation products with amino acids.

These colored substances were prepared synthetically and the spectrophotometric transmittancy curves compared with those for raw sugar crystals. The curves appear qualitatively the same.

The thermal decomposition products are pH sensitive, showing much higher color at higher pH. The melanoidin shows little change of color with pH.

These results demonstrate the importance of pH and temperature on the development of color. Since both the reducing sugars and amino acids are naturally present in all juices, control of color from these materials can only be accomplished by control of conditions during crystallization.

INSECTS

THE CANE INSECT PICTURE

The sugar-cane borer *Rhabdoscelus obscurus* (Boisd.) continues to occupy first place among our insect pests. The species is evidently maintaining economic levels of population everywhere and was observed as particularly harmful at Lihue and Grove Farm on Kauai, Hilo Sugar Company, Ltd. and Olaa on Hawaii, and Pioneer Mill Company, Ltd. on Maui. There is little doubt that long cropping will continue to influence the abundance of this insect and that the level of its population in our fields is bound to remain higher than in the past. The only feasible way to better the situation still appears to be the introduction of parasites able to supplement the work of *Microceromasia sphenophori,* if these can be found.

Anomala orientalis (Waterhouse), in contrast with the sugar-cane borer, has not held the relative abundance it had attained during the last biennium, and the rate of its spread into Waialua has remained slow. It has continued to spread, however; and at last record, numerous beetles had been collected in Field Opaeula 17 in April, and a considerable population of grubs was found in Field Kemoo 2A in August. As far as is shown by evidence, these two fields mark, respectively, the northeast and southeast corners of *Anomala's* latest spread. Fortunately, the efficient parasite *Campsomeris marginella modesta* (Smith) continues to hold its own in the new as well as the old territory of *Anomala,* and has so far prevented the recurrence of commercial damage.

Continuing the trend of the last several years, neither cutworms nor armyworms were seen in the cane fields of any island, and only two species attracted attention elsewhere. The first of these was *Pseudaletia unipuncta* (Haworth), which has continued to build up destructive populations periodically in the grass ranges of Hawaii, above the cane fields; and the second, the so-called lawn armyworm, *Spodoptera mauritia* (Boisduval), which spread this year to the islands of Maui and Hawaii. On Hawaii, this armyworm was first noticed in the yard of the Experiment Station's substation at Wainaku, Hilo, wreaking havoc on the geneticists' potted seedlings of the 1959 series. It is now apparently established in the vicinity of the substation, and it will probably prove troublesome again in years to come. Fortunately, however, the species has not taken to field crop cane in any of the islands, and it probably will not do so.

The sugar-cane leafhopper *Perkinsiella saccharacida* Kirk., made its most notable appearance in many years during the first three months of 1959, in Field Helemano 6 of Waialua. About 20 acres of the field were involved, and eight to 10 acres were damaged to an extent which will probably show at harvest. Beyond the fact that it involved 38-2915, a soft variety, the causes of the outbreak were not determinable; but its quick reduction was unquestionably brought about by parasites, among which the mirid bug, *Cyrtorhinus mundulus* (Bredd.), again proved its pre-eminent usefulness.

Only one case of unusual abundance occurred among minor pests. This was in the Kapoho section of Olaa, where the larvae of a tenebrionid beetle, *Eutochia lateralis* (Boh.), prevented germination of about one-third of the seedpieces in a one-acre experiment put in by the Pathology Department. Previously the insect had injured seed cane noticeably only once, at Kohala, Hawaii, in 1922.

The application of Dieldrin granules, at a rate of three pounds of actual Dieldrin per acre, was recommended as protection for the replant seed of the experiment and has apparently proved successful.

Mealybugs continue to receive special attention. The results of three years of work on the taxonomy of the pineapple mealybugs of Hawaii, which includes species important to sugar cane as well as to pineapple, are now in print and clarify questions which may bear importantly on problems related to biological control of the species.

On another phase, a beginning has been made in an attempt to use the proboscis of mealybugs and other related insects to connect the phloem of sugar cane with delicate instruments designed to study the movements and composition of sap within the plant. This is to be a joint project of the departments of Entomology and Physiology.

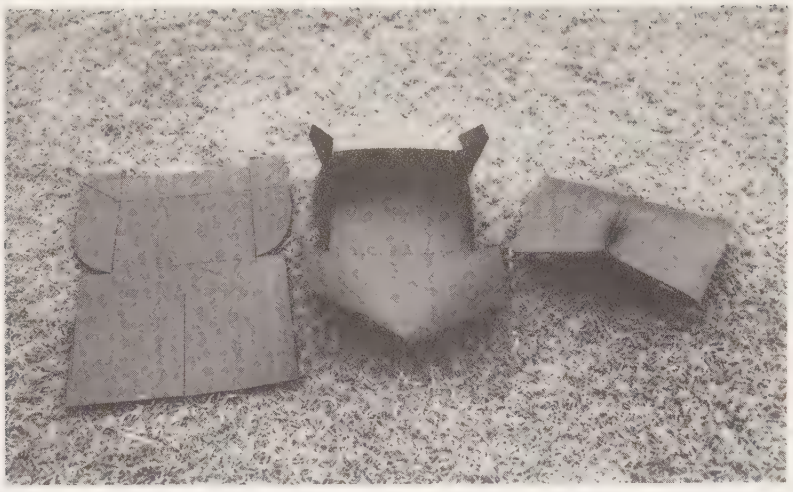


Figure 31. One of several experimental designs for a poison-oats feeding station.

RAT CONTROL RESEARCH PROGRAM INTENSIFIED

In the field of rodent control the department has been particularly busy in an advisory capacity, putting in about 80 man-days on plantations of the outer islands, studying their individual problems and cooperating in their solution. Operational improvements have resulted from this effort on several plantations, and two of them, Grove Farm on Kauai and Pepeekeo Sugar Company on Hawaii, have undertaken to remodel their programs completely on the strength of recommendations.

Grove Farm, as of May, reorientated its program to the prebait method of poisoning, and has abandoned the use of anticoagulants, except in special circumstances. The plantation made this decision when it became evident that the anticoagulant-based program was not effectively suppressing the rat population. Coincident with the change-over, the personnel and transport facilities of the program have been expanded and it has been made the entire responsibility of a full-time supervisor.

At Pepeekeo, trapping of several fields, conducted by the Entomology Department in January, showed dense populations of Norway rats—the species most harmful to cane—in spite of abatement measures which had been carried out continuously for several years. As a result, the program has been strengthened with additional manpower and materials, and its sound development has been assured by coordinating it to the guidance of carefully recorded data related to trapping and bait consumption.

While the program at Pepeekeo is still based on anticoagulants, the use of the ordinary quonset-hut-type of station is being gradually curtailed, and the use of a cardboard-drum-type "permanent" station is being expanded. Eventually, about 500 of these drums will be installed and, since they retain their effectiveness for many weeks without attention, they are expected to result in greater economy and efficiency for the program. They can be installed anywhere, even as substitutes for ordinary stations, but their best use is along the intransitable back borders of fields, which formerly remained unprotected from the time the cane closed in until harvest.

Other plantations, Lihue, Grove Farm and Kilauea Sugar Company, Ltd. on Kauai, Hilo Sugar and Olaa on Hawaii, and Pioneer Mill on Maui, are also expanding the use of permanent drum-stations, and it is apparent that this will eventually become a tool of major importance in rat abatement. At present, the original type devised at Lihue in 1956 is the best known; but several variations of the original are also employed, depending on the kind of drum and building material available on each plantation. Eventually, it is expected that some features of all the models will become standardized in accordance with principles of economy and efficiency which this department is now investigating.

As large drum-stations are not likely to displace

smaller, cheaper, and more portable stations entirely, these have also been looked into by the department with the object of developing a type which will last longer under adverse conditions and protect the grain from birds and weather better than the cardboard stations in current use (Figure 31). Several designs and materials have been investigated, but the optimum combination of design and material is still being sought. It has become quite obvious that the Waialua-type of cardboard stations are very far from the optimum and that their cheapness has been overbalanced many times in the course of the years by their short life and the tons of oats which have been sacrificed in them to the weather and the birds.

No new poisons or carriers were developed by the department during 1959, but two field tests of the Endrin dog biscuit combination, discovered in 1958, were conducted on Kauai and Hawaii, respectively. The first of these tests was attended by unfavorable circumstances and failed to produce significant results. The second test, larger than the first and in a more propitious environment, verified laboratory conclusions as to the value of the new rodenticide in combatting rats, particularly the Norway rat, in areas inaccessible to ordinary measures.

The Endrin biscuits employed in the two tests were obtained through the cooperation of the Pacific Chemical & Fertilizer Co., the Velsicol Chemical Corporation, and the manufacturers of the original dog biscuit bought in the open market for our tests of last year. The formula of their composition is said to be identical with that of the pet food, but their size and shape are better adapted to the functions of a carrier which will be broadcast mechanically or by hand. They are shaped like oyster crackers of a half-inch diameter, weigh an average 2.8 grams per unit, and at a concentration of 2.5 per cent Endrin by weight, carry enough poison to kill more than 30 of the largest Norway rats. It is believed that for maximum effect they should be broadcast at a rate of about 10.75 pounds to the acre. This should result in a distribution of one biscuit for every five-foot square, and cost about $4.80 per acre for materials.

In the test conducted at Olaa, Pahoa Field 65, the baits were hurled by hand to both sides of paths cut through cane approximately 22 months old. One of the paths was 1000 feet long and the other 950 feet, and the average width of the area treated was estimated at about 50 feet, so that the biscuits were distributed at a rate of one for every 19 square feet, which is considered an unnecessarily high density.

The effect of the application was judged by comparing the results of pre-treatment and post-treatment trapping along the two paths and along two check lines laid in the same area of the field. The trapping, simultaneous along the four lines, was done on the two days immediately preceding the treatment, and on the sixth and seventh day following the treatment. The results are shown in Table 7.

Analysis of the results shows a reduction of 72 per cent in the combined populations of the two test areas, against a reduction of 15 per cent in the combined populations of the two check areas. Ideally, no change should have appeared in the checks; but in the case of this particular test, the slight reduction observed (all of which occurred in check line #2) does not diminish the significance of the much greater reduction measured in the test areas. This contention is based on the fact, evinced by the results themselves, that the check areas were not fully representative of the test areas, either in the composition or the density of their rat population. The contention is further strengthened by the strong probability that the checks were too near the test areas to escape completely the effect of the poison.

Table 7

	Pre-treatment	Post-treatment	Per cent reduction
Test Line #1			
Norway females	17	1	94%
Norway males	16	7	56
Others	3	0	100
Total	36	8	77
Test Line #2			
Norway females	7	3	57
Norway males	16	5	68
Others	6	2	66
Total	29	10	65
Check Line #1			
Norway females	3	4	
Norway males	3	3	
Others	1	1	
Total	7	8	14 (increase)
Check Line #2			
Norway females	4	4	
Norway males	4	3	
Norway not sexed	1	0	
Others	3	1	
Total	12	8	33%

The larger reduction of female Norways (83 per cent) than of Norway males (62 per cent) is in accord with our experience of Endrin characteristics and indicates that the over-all reduction in the treatment areas was due to this poison. Reduction by other factors was not likely to have resulted in a sexually differentiated ratio.

Laboratory experience has shown that most rats succumb quickly to the effect of Endrin biscuits, but that there is always a considerable segment of the population which takes longer to die, in some cases several days. It is reasonably certain, therefore, that the results of the present test do not represent the maximum kill that could have been measured if the post-treatment trapping had been delayed a week or longer beyond the dates when it was actually conducted. This was not done for fear that encroachment of unpoisoned rats from the surrounding area would vitiate the results more than early trapping.

In an experiment involving a large area, particularly a discrete area, need for this precaution would have been obviated, and the results would have been more striking.

This consideration seems to justify the conclusion that Endrin biscuits possess high potential value in the control of rats, particularly Norway rats, in overgrown cane fields and other areas not within reach of ordinary abatement measures.

IRRIGATION

WAIALUA STUDIES ON GROUND-WATER USAGE

Waialua has three large pumping stations, pump 1, pump 2, and the mill pump, totalling about 35 mgd draft, located at the extreme western edge of the Kawailoa ground-water body in Koolau lavas. The excessive local draft results in high salinities. Studies have been commenced on the advisability of shifting a part of the draft to new wells in the Mokuleia ground-water body in Waianae lavas. Possible new well sites have been located, and an old test hole with uncertain records was deepened to rule out one possible site. Relocation of pump 5 was also studied.

The yield of the Kohala mill pump was limited by excessive sump drawdown. The tunnel system was inspected and the pumping limitation found to be in a shallow sill that prevented full drawdown in the tunnels.

It is certainly advisable to shift some of the Waialua mill area draft from the Kawailoa to the Mokuleia ground-water area. The safe yield of the latter is not known. Hence a gradual shift is in order. This is consistent with development by drilled wells and individual pumps.

Fortunately, three sites were found that on preliminary indications seemed probably satisfactory for such development. One was suggested by some of the reported results of a test hole T-30, other results of which, however, seemed inconsistent. T-30 was deepened, indicating that it penetrates Koolau lavas isolated by a buried Kaukonahua Valley, and not Waianae lavas as earlier reported. The area of T-30 is, therefore, not suitable for development, but two other areas of probable suitability remain.

IMPROVED MAXIMUM-MINIMUM THERMOMETER AVAILABLE

The Weather Bureau type of maximum and minimum thermometers are unreliable in plantation field use. The standard Six's type of max-min is not adequately sensitive. Taylor Instrument Company was asked, through P. S. Pell & Co., to develop a more sensitive type of Six thermometer for Hawaiian conditions, and sufficient orders were procured to justify their manufacture.

The new Six's type max-min thermometer has a restricted range and double the sensitivity of the old model, and has been recommended to all plantations for field use in place of both the old Six's and Weather Bureau type instruments. Nearly 100 have been obtained for the sugar industry.

The Instrument Shop is working on a new, cheaper and more durable shelter to accommodate these instruments.

RADIATION INSTRUMENTS COMPARED

Seasonal shifts in the calibration of actinometers have been discovered in connection with the evapotranspiration experiment, and are under study by com-

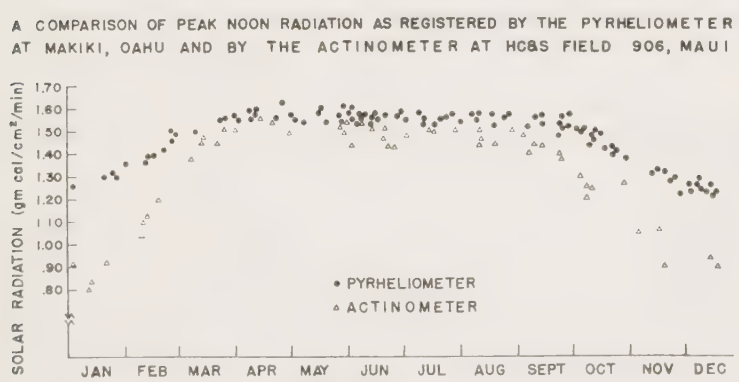


Figure 32.

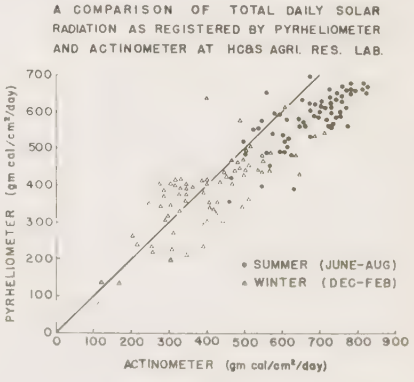


Figure 33.

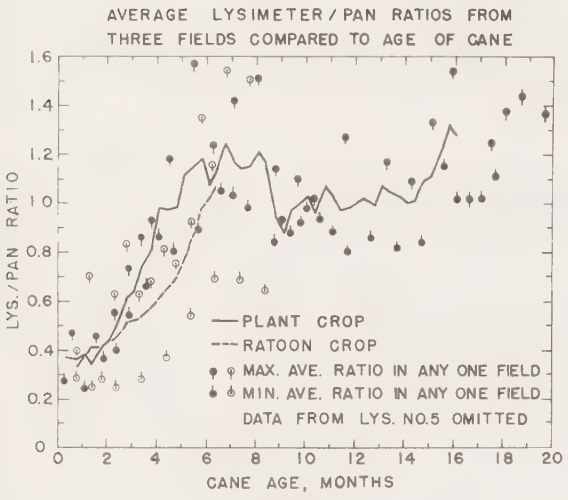

AVERAGE LYSIMETER / PAN RATIOS FROM
THREE FIELDS COMPARED TO AGE OF CANE
LYS./PAN RATIO
CANE AGE, MONTHS
PLANT CROP
RATOON CROP
MAX. AVE. RATIO IN ANY ONE FIELD
MIN. AVE. RATIO IN ANY ONE FIELD
DATA FROM LYS. NO.5 OMITTED

Figure 34.

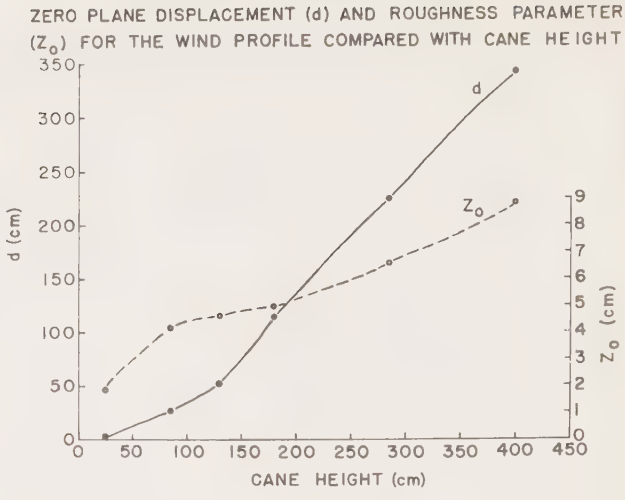

ZERO PLANE DISPLACEMENT (d) AND ROUGHNESS PARAMETER
(Z_0) FOR THE WIND PROFILE COMPARED WITH CANE HEIGHT
d (cm)
Z_0 (cm)
CANE HEIGHT (cm)

Figure 35.

parison with pyrheliometers. The manufacturers were not aware of the discrepancy.

The seasonal actinometer calibration shift was discovered first through a comparison of indications by actinometers and a pyrheliometer of noon sunshine intensity on clear days, when it is assumed that the actual intensity is nearly the same at all low-altitude stations in Hawaii. It was found, however, that the actinometers consistently under-registered the winter intensity by about 20 per cent if corrected for summer conditions (Figure 32). It is still uncertain whether the discrepancy is due to a non-linear response, a specular reflectivity effect varying with angle of incidence, a result of seasonal variation in dew-fogging, or some other cause. The only record of actinometer and pyrheliometer operation at the same station (Figure 33) suggests some non-linearity in response.

The HC&S pyrheliometer was found on comparison with other pyrheliometers to under-register by 10 per cent at high sunshine intensities, though at low intensities it appeared satisfactory. The manufacturer has supplied a replacement.

Calibration of photochemical sunshine integration tubes has been recommenced, because anticipated substitute field methods for sunshine integration have not materialized.

PLANTATION CLIMATOLOGICAL STATIONS INSPECTED

Climatological stations at two plantations on Maui, two on Oahu, and eight on Kauai have been inspected. The location, exposure, and surrounding environment of each station were studied and plotted on maps. Instruments were inspected.

Twenty-five sites for installing evaporation pans have been tentatively selected at nine plantations to permit correlation of pan evaporation with normal irrigation practice. The sites recommended at McBryde Sugar Company, Ltd. and Waialua have been checked in the field.

Rainfall data of 80 stations in East Maui have been punched on IBM cards. A study is being made to determine how dense a network is necessary in that area by computing the inter-station rainfall correlations.

A new climatological reporting form, which includes not only temperature but also humidity, has been issued for plantation use.

EVAPOTRANSPIRATION EXPERIMENT PRODUCING VALUABLE RESULTS

Essentially the same instrumentation and recording program is being maintained for the ratoon crop as for the plant crop in the lysimeter evapotranspiration experiment at HC&S. Lysimeter-pan ratios have been computed to date, but the full-scale computer analysis of the general data has not yet been attempted, partly because of lack of machine time and partly because of the uncertainty of appropriate corrections to the actinometer data.

Pan evaporation, radiation, temperature, humidity, and wind data are being recorded in the MASI field, near one of the lysimeter plots, where evapotranspiration may be estimated from the soil-moisture-tension data and irrigation applications.

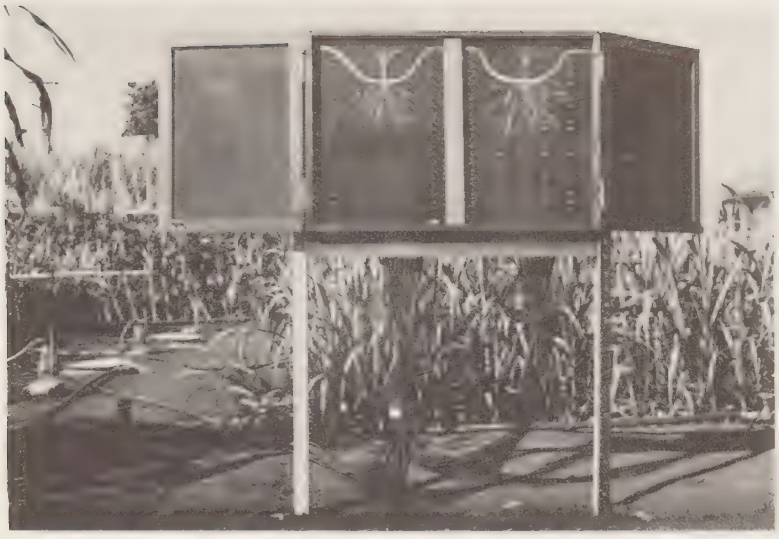


Figure 36. The terminal panel for the Bouyoucos blocks is installed in plots II and III. Each pair of terminals represents a single block. The bottom blocks are 30 inches below the bottom of the row. Root development may be followed by block moisture as indicated in the photograph.

The lysimeter-pan ratios from the evapotranspiration experiment are summarized in Figure 34. It will be noted that the ratios increased with the growing plant crop from about 0.4 to an average of about 1.1 for a well-developed canopy. The standard deviation about this average was 0.2. The ratoon crop appears to be following essentially the same pattern.

The first month's data tested in the MASI experiment have yielded an average cane evapotranspiration/pan evaporation ratio of 1.0 for cane with a complete canopy, closely checking the results from the evapotranspiration experiment.

The effect of cane growth on the wind profile is being studied at Waipio as a preliminary to possible application of an aerodynamic approach to evapotranspiration. It is generally known that the wind speed increases exponentially with height over a smooth surface. Over a moderately rough surface, e.g. short grass, the logarithmic wind profile holds true only above a hypothetical height Z_o, known as the roughness of the surface. Over a very rough surface, such as tall vegetation which acts somewhat like a solid mass, the normal turbulent exchange takes place mainly above a datum level d, the zero plane displacement, which is roughly of the order of the depth of the layer of air trapped among the plants. Both Z_o and d are, therefore, geometric constants of the surface. Figure 35 illustrates how these two constants increase as the cane grows, as determined by a study at Waipio. From the standpoint of evapotranspiration study, it should be emphasized that, other things being equal, evapotranspiration increases with the roughness of the surface.

The heat budget approach is being investigated at Makiki by a comparison between incident radiation, albedo, and net radiation over a Physiology and Biochemistry plot in which sub-canopy radiation and evapotranspiration are being simultaneously recorded.

Though these results show that the calculation of evapotranspiration from climatic data is still not indicated as a field guide to irrigation scheduling, it appears that pan evaporation, at least, is a useful guide to over-all water use. Pans have, therefore, been recommended for installation at a number of plantations.

ENVIRONMENTAL FACTORS CONTROLLING DEVELOPMENT AND WATER CONSUMPTION OF SUGAR CANE

In order to determine at what stage of growth the consumptive use of water from a transpiring field of sugar cane reaches a maximum, and also the factors which control consumptive use of water, three plots, 35×20 feet, were planted to variety 37-1933 on January 7, 1959, at the Makiki Station.

Figure 37. Miniature lysimeters were installed in three plots. The track and car to carry the pyrheliometer may be seen between Rows #4 and #3 of the plot in the foreground.

In one of the inner rows of each plot, Bouyoucos gypsum blocks were buried to obtain information on soil moisture. The blocks were arranged to form a grid which extended from the center of each bank at a depth of 30 inches. The horizontal distance between the blocks was one foot, and the vertical distance six inches. Daily readings were made (Figure 36).

Within each of the plots, miniature lysimeters of 25-gallon capacity were installed in several of the rows. Each lysimeter contains single stalks of five plants protruding through holes in metal covers. There is no loss from evaporation or leakage into the containers from rain (Figure 37).

In addition to these lysimeters, plants growing in five-gallon containers were placed in the rows. These plants are irrigated by auto-irrigating cones connected to reservoirs which are placed outside of the plots. These containers are also covered to prevent evaporation and entrance by rain. The aerial portion of the plants thus placed becomes an integral part of the leaf canopy of the plants in the ground and all plants should, therefore, respond in a similar manner to weather conditions.

Certain weather data are obtained and each component or combination of components will be studied in relation to the consumptive use of water. The weather data obtained are: total solar radiation, air temperature, humidity, and wind velocity. Data from several types of evaporimeters are obtained. These include data from a standard four-foot pan, black and white atmometers, both spherical and flat, and data from shallow evaporimeters 25 inches in diameter.

The stage of growth at which the leaf canopy intercepts the maximum amount of solar energy is determined by the difference between the energy received by an unobstructed pyrheliometer and one which slowly moves back and forth on top of a bank the length of the plot. This measurement will also be

Table 8

Dates Between Irrigations	Interval Days	Inches Applied	Cumulated in.	Evaporation Inches	Cumulated Evaporation
February 27 to March 2	4	.5	.5	.264	.264
March 3 to March 19	17	.5	1.0	2.476	2.740
March 19 to April 20	31	2.0	3.0	7.563	10.303
April 21 to April 26	6	.5	3.5	1.559	11.862
April 27 to April 30	4	.75	4.25	1.170	13.032
May 1 to May 7	7	1.0	5.25	1.886	14.918
May 8 to May 14	7	1.5	6.75	1.701	16.619
May 15 to May 28	14	1.0	7.75	2.957	19.576
May 29 to June 2	5	1.0	8.75	1.518	21.094
Total	95	8.75		21.094	

made with long glass tubes employing the photochemical method for the integration of light. The tubes will be placed in the furrow and on the bank.

All irrigation water is measured by a meter and with the grid arrangement of blocks it becomes possible to know the wet and dry zones and, therefore, the limit of water which may be applied without percolation loss from the root zone. All of the water applied can be accounted for as having been removed by evapotranspiration.

Since the start of the project there has been no interference by rain, which will make it possible to determine the transpiration ratio of variety 37-1933 with a high degree of accuracy for a given age when harvested.

To obtain data on the phenology of sugar cane, physical measurements were made of the plant which included daily spindle growth, weekly stalk growth and leaf area.

Evapotranspiration and evaporation data are shown in Tables 8 and 9. Table 8 shows the data for sugar cane up to five months of age prior to closing in, and Table 9 shows the data from the time the leaf canopy almost completely shaded the ground.

If the volume of soil of a single line is considered as an isolated unit, the value of $\frac{ET}{EP}$ may be determined where ET equals evapotranspiration and EP equals evaporation from a free water surface. A correction factor must be applied to compensate for the extension of the leaf canopy past the end of the line.

ET equals 15.0 and EP equals 15.8. Measurements were made of the shadow cast by the overhanging canopy at the ends of the line and this was found to be very close to three feet for each end, or a total of six feet. As the lines are 20 feet in length, the factor $\frac{20}{26} = .77$ must be applied to the ratio $\frac{ET}{EP}$. For the conditions of this experiment, ratio $\frac{ET}{EP}$ becomes $\frac{15.0}{15.8} \times .77 = .73$.

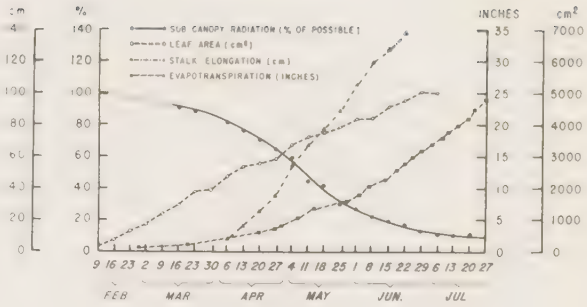


Figure 38.

Figure 38 shows the decline of solar radiation reaching the ground as the leaf canopy develops. This is expressed as per cent of possible, and reached a minimum value when the sugar cane was about six and one-half months of age. This coincides closely with the time at which the leaf area became a maximum. It is at this stage that the leaf canopy is receiving all of the solar energy possible for photosynthesis and transpiration, and marks the start of the boom stage of growth. The consumptive use of water by the sugar cane also shows an increase at about this stage of growth as shown in Figure 38.

Figure 39 shows the accumulative evaporation from a standard pan and the accumulative evapotranspiration from a plot of sugar cane between the dates of June 7 and July 29.

Table 9

Dates Between Irrigations	Interval Days	Inches Applied	Cumulated in.	Evaporation Inches	Cumulated Evaporation
June 3 to June 7	5	1.5	1.5	1.333	1.333
June 8 to June 14	7	1.0	2.5	1.985	3.318
June 15 to June 18	4	1.5	4.0	1.230	4.548
June 19 to June 22	4	1.0	5.0	1.174	5.722
June 23 to June 25	3	1.0	6.0	.907	6.629
June 26 to June 29	4	1.0	7.0	1.157	7.786
June 30 to July 3	4	1.0	8.0	.954	8.740
July 4 to July 8	5	1.0	9.0	1.315	10.055
July 9 to July 11	3	1.0	10.0	.852	10.907
July 12 to July 15	4	1.0	11.0	1.121	12.028
July 16 to July 19	4	1.0	12.0	1.137	13.165
July 20 to July 23	4	1.5	13.5	1.096	14.261
July 24 to July 29	6	1.5	15.0	1.551	15.812
Total	57	15.0		15.812	

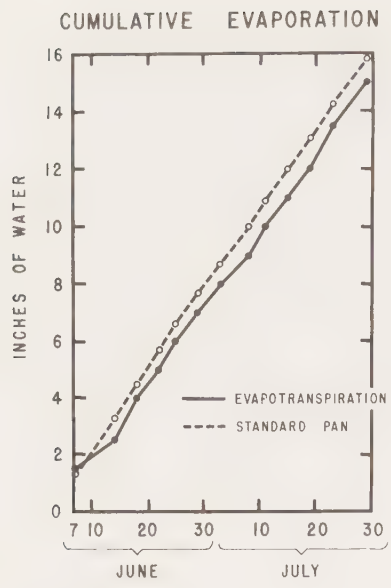


Figure 39.

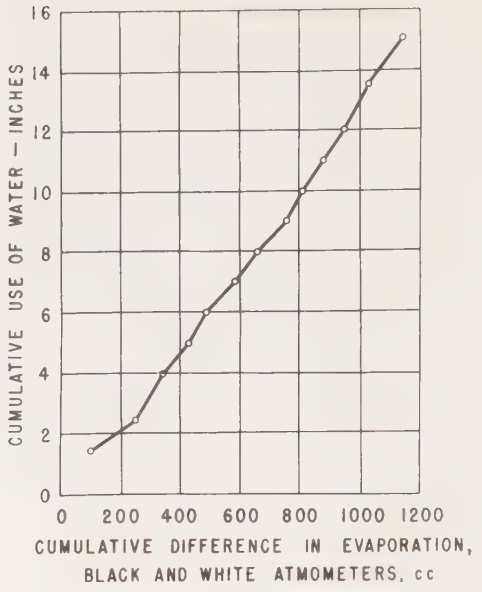


Figure 40.

Figure 40 shows the cumulative difference between a black and white atmometer and consumptive use by sugar cane.

STUDIES CONTINUE ON WATER DISTRIBUTION IN FURROW IRRIGATION

The advance method for determining water distribution offers many advantages over other methods. Studies were conducted during 1959 at Olokele Sugar Company, Ltd., Oahu Sugar and HC&S. The method produces an equation as follows:

$$Q = a' \; a \; t^{b}$$

Q = depth of application

a and b are parameters to be determined for each soil

a′ depends upon the furrow spacing and wetted surface within the furrow

t = infiltration time for any position in the furrow

Examples of equations were determined for two areas:

(1) Field 88, Oahu Sugar

$$Q = a' \; 1.74 \; t^{0.68}$$

(2) Field 510, HC&S

$$Q = a' \; 2.10 \; t^{0.67}$$

To determine water distribution once the equation is established, water surface width, furrow spacing and infiltration time are observed during normal irrigation. These values are substituted in the equation.

Table 10 shows the water distribution for three furrows using the advance method.

The relationship of furrow slope is being continuously investigated. During 1959, harvest data were collected at Lihue and Oahu Sugar. Additional tests have been installed at Olokele and Oahu Sugar.

Table 10. Water Distribution in Furrows Using the Advance Method

Distance from flume	Furrow		
	1	2	3
ft.	inches	inches	inches
10	16.1	11.0	7.8
40	10.0	9.4	7.8
70	12.1	16.0	11.3
100	11.0	10.9	10.6
130	9.2	11.0	5.4
160	3.9	4.0	3.8

The relationship between water distribution and improvement in the layout by land smoothing is being tested at Olokele.

A study is progressing at Kahuku Plantation Company to determine if the between-cane-line irrigation uses less water more advantageously than the standard in-furrow technique.

EXPERIMENT MASI PROVIDES DATA FOR OVERHEAD IRRIGATION

During the year 1959, the irrigation of Experiment MASI has progressed satisfactorily. A new rotating boom infiltrometer was constructed and put into operation to maintain a rigid irrigation schedule.

The desirability of using a continuous irrigation period is apparent from the data presented in Table 11. In this particular test, only part of the application

Table 11. Effect of 16-hour Delay During Irrigation Period on Infiltration Rate of Waiakoa Silty Clay Loam

		Infiltration Rate	
	Time	Flat 1.0% slope	Ridge 1.2% slope
Plot B-9 12/5, 6/1958	(min.)	in./hr.	in./hr.
	0	0.46*	0.46*
	20	0.46	0.46
	40	0.46	0.46
	60	0.35	0.45
	80	0.33	0.41
	100	0.31	0.37
	120	0.29	0.34
* Application rate.			

		Infiltration Rate	
	Time	Flat 1.0% slope	Ridge 1.2% slope
	(min.)	in./hr.	in./hr.
16 hours elapsed	0	0.52*	0.52*
	20	0.20	0.43
	40	0.11	0.15
	60	0.10	0.13
	80	0.10	0.13
	100	0.10	0.13
	120	0.10	0.13
* Application rate.	140	0.10	0.13

was applied by "pau hana time". This required continuing the application the next morning. The results show an infiltration rate of about one-third inch per hour at 4:00 p.m. on December 5, and at 10:20 a.m. December 6, the intake rates were about 0.10 inch per hour, or about one-third the terminal value for the previous day. This effect is important in determining how to operate overhead irrigation equipment. This same effect is operative in furrow irrigation.

Tests were initiated to determine the maximum depth of application that can be made with a traveling boom applicator. This information is being developed to provide a basis for determining the travel speed of equipment and rate of water delivery to the soil surface. Table 12 gives preliminary results.

In essence, the problem is to provide sufficient time-opportunity for infiltration to obtain the desired application. The above test shows that no more than 0.6 of an inch per pass should be applied. Further studies will show how the soil changes under repeated applications at various moisture contents.

SLOPE AND CONDITION OF SURFACE AFFECT INFILTRATION OF WATER FROM OVERHEAD IRRIGATION

The translating boom infiltrometer has been used to study the entry of water into various soils which may eventually be irrigated with overhead irrigation equipment. Only one soil type is reported here to illustrate the relative magnitude of the effect of slope

Table 12. Relationship of Intake to Boom Speed and Energy Imparted to the Soil Surface During Application

		Low Energy Application*			High Energy Application**		
Pass No.	Boom Speed	Application	Runoff	Wetted Depth	Application	Runoff	Wetted Depth
	(ft./min.)	(inches)	(%)	(inches)	(inches)	(%)	(inches)
1	8	0.64	15.6	2.7	0.62	19.4	2.4
1	1	0.61	0.7		0.51	0.8	
2		0.62	17.7		0.51	39.2	
3		0.60	26.7		0.49	42.9	
4		0.62	43.5	8.28	0.51	70.6	5.1

* Water intercepted at the soil surface by two layers of burlap cloth.
** All water delivered to the surface at terminal velocity for drops ranging below 6 millimeters in diameter.

Table 13. Effect of Slope on the Infiltration Rate of Water Into Paia Silty Clay Loam

		Irrigation #1		Irrigation #2		Irrigation #3	
Slope	Surface Treatment	Appl.	Av. Inflt.	Appl.	Av. Inflt.	Appl.	Av. Inflt.
(%)		(in./hr.)	(in./hr.)	(in./hr.)	(in./hr.)	(in./hr.)	(in./hr.)
0.0	Furrow, bare surface	3.92	3.51	3.78	2.46	3.87	2.58
2.0	Furrow, bare surface	3.92	3.18	3.78	2.36	3.87	2.36
	Difference		0.33		0.10		0.26
0.0	Ridge, bare surface	3.94	3.42	3.82	3.26	3.85	3.19
2.0	Ridge, bare surface	3.94	3.36	3.87	3.01	3.75	3.03
	Difference		0.06		0.25		0.17
0.0	Flat, bare surface	4.20	3.78	3.83	3.06	3.93	3.50
5.0	Flat, bare surface	4.04	2.52	3.70	2.28	3.78	2.64
	Difference		1.26		0.78		0.86

Table 14. The Effect of Surface Shape in Intake Rate for Paia Silty Clay Loam

Irrigation Round	Furrow	Ridge	Flat
	(in./hr.)	(in./hr.)	(in./hr.)
1	3.51	3.42	3.78
2	2.46	3.26	3.06
3	2.58	3.19	3.50
Mean	2.85	3.29	3.44

of land, shape of surface, and cover applied to the surface as a thin trash blanket.

Water was applied by a boom spray traveling about 68 feet per minute. A pass was made once every 2.6 minutes, giving an average application rate of 3.88 inches per hour. Some of the plots in the furrowed and ridged layout were basin-listed. In addition to these, one-half of the plots were bare, and the rest were covered with a thin layer of cane trash. No runoff occurred on either the trash-covered or the basin-listed plots. The effects of slope variations on intake rates are given in Table 13. In the furrowed area, 8.1 per cent more runoff was measured from the plots with 2.0 per cent slope than from those with 0.0 per cent slope. In the ridged surface, this same slope effect was 4.9 per cent. However, in the flat plots, the grade difference was five per cent, which gave 28 per cent increase in runoff. The effect of surface shape on average intake rate is seen in Table 14. The furrowed surface is less effective than either the flat or ridged surface. This result is explained on the basis that there is less opportunity for water intake by the soil because of the steep sloping ridges.

FURROW SHAPE AFFECTS WATER USAGE UNDER SURFACE IRRIGATION

Studies were initiated in 1959 to determine the influence of furrow shape on the quantity of water required for adequate irrigation. Similar tests were installed in Field M at the HSPA Waipio Substation and in Field 74 at Oahu Sugar. In both tests, "U"-shaped furrows were made with Oahu Sugar's planting machine, and "V"-shaped furrows were formed with Waialua's planting machine. Plots were either eight or 10 furrows wide and about 200 feet long. Water was measured to each plot, keeping the flow rate constant for duration of irrigation. The irrigation time was determined by allowing the water to form a small pond at the tail end of each furrow be-

Table 15. Depth of Water Applied to "U" and "V" Shaped Furrows in Field M, Waipio Sub-Station

Plot	Shape	Length	Slope		Water Line Width	Depth Applied		
			Desired	Actual		Rd. 1	Rd. 2	Rd. 3
		(ft.)	%	%	(in.)	(in.)	(in.)	(in.)
1	U	190	1	1.1	18.7	3.82	1.47	1.24
2	V	190	1	1.0	15.1	2.99	1.28	1.28
					3.6	0.83	0.19	—0.04
8	U	200	1	1.1	19.9	8.68	2.24	1.73
7	V	200	1	1.0	14.5	6.30	1.92	1.69
					5.4	2.38	0.32	0.04
4	U	200	2	1.8	18.2	3.24	1.37	1.23
3	V	200	2	1.7	12.6	2.01	0.96	0.96
					5.6	1.23	0.41	0.27
6	U	200	2	1.8	17.3	4.98	1.55	1.42
5	V	200	2	1.9	13.7	1.96	0.91	0.96
					3.6	3.02	0.64	0.46
						Average difference		0.81

Table 16. Depth of Water Applied to "U" and "V" Shaped Furrows

Plot	Shape	Length	Slope		Water Line Width	Depth Applied		
			Desired	Actual		Rd. 1	Rd. 2	Rd. 3
		(ft.)	%	%	(in.)	(in.)	(in.)	(in.)
1	U	200	1.75	1.7	17.2	3.40	3.30	3.20
2	V	200	1.75	2.0	15.7	3.81	4.18	3.71
						—0.41	—0.88	—0.41
3	U	190	1.75	2.6	16.5	4.03	4.62	4.19
4	V	190	1.75	2.5	15.5	3.31	3.17	3.60
						0.72	1.45	0.59
5	U	200	1.75	2.4	16.5	3.04	3.30	3.35
6	V	200	1.75	2.8	13.4	3.87	3.56	3.76
						—0.83	—0.26	—0.41
						Average difference		—0.05

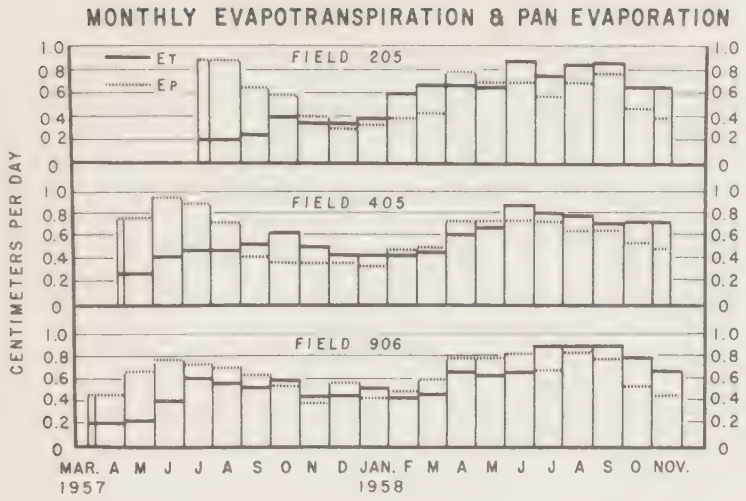


Figure 41. Evapotranspiration and pan evaporation from lysimeters are shown for the plant crop at HC&S.

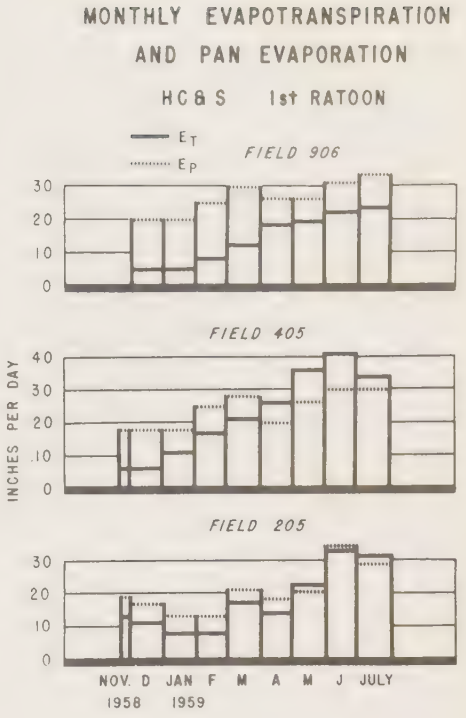


Figure 42. Evapotranspiration and pan evaporation in lysimeters are shown for the first eight months of the first ratoon crop at HC&S.

fore terminating the irrigation period. Slope profiles were measured in 10-foot increments and water surface widths were obtained during irrigation corresponding to these same increments. In Table 15, the field observations are shown in relation to the shape and slope treatment combinations. The water line width (WLW) for each plot is composed of 160 field measurements. The difference in WLW between the "U" and "V" shapes averaged 4.6 inches. There were significant differences in the depth of application in the first round for all slopes, but the differences are very much less pronounced in the third irrigation. The results show a saving of 0.81 inch per round in favor of the "V"-shaped furrow.

A summary of Field 74, Oahu Sugar, is shown in Table 16. In general, there is no significant difference from this test, even though there are real differences in WLW. In this field, the irrigation data reflect uneven grades in the furrows. The surface soil in Field 74 is very permeable whereas the subsoil is less permeable; hence there is considerable lateral amount of water, particularly when water ponds in low spots in the furrows.

The tests show that one can expect different results depending upon the soil profile and normally occurring field irregularities. It is proposed that these studies be carried through harvest in order to permit a general conclusion which would apply to plantation operation.

WATER REQUIREMENTS OF SUGAR CANE

Sugar-cane evapotranspiration measurements in lysimeters at HC&S have been made continually since 1957. Nine lysimeters which are all located on Maui were harvested in November 1958, when the canes were 16, 19 and 20 months of age for Fields 205, 405 and 906, respectively. The results obtained for this plant crop have been reported in detail in the Proceedings of the Tenth Congress of the ISSCT. In Figure 41, the water-use results are given for the plant crop. The average use rate was 0.22 inch per day.

In the ratoon crop, the evapotranspiration and pan evaporation data are presented in Figure 42 to include July 1959. During the four winter months, November through February, the evapotranspiration averaged .09 inch per day. From March to May, there was a sharp rise in evapotranspiration. The months May, June and July averaged 0.29 inch per day.

For the four-month period, April to July 1959, a period when the cane canopy was closed in, the evapotranspiration/pan evaporation ratio was 0.99,

which means the cane used nearly as great a depth of water as was observed to evaporate from a pan mounted on a tower kept at cane top height.

Observation of primary stalk elongation (variety 37-1933) on soils of the Makaweli series, Molokai family at Olokele, and simultaneous readings of helical coil gypsum block resistance have provided data that can be used for interval control recommendations. Growth rates of 2.5 inches per week may be expected where moisture tension at the 12-inch depth is allowed to reach 0.7 to 0.9 atmospheres or where tension at the six-inch depth is allowed to reach 2 to 4 atmospheres. Growth rates decline to zero as soils dry to tensions of 10 to 15 atmospheres.

Where soil at the 12-inch depth is kept wetter than 0.7 to 0.9 atmospheres, growth rates are greater than 2.5 inches per week, the specific rate being dependent upon factors other than irrigation.

FERTILIZATION IN IRRIGATION WATER MAY PRODUCE UNEVEN GROWTH

Uneven, drying and dying cane during last year's four-month strike re-emphasized the fact that water distribution is far from satisfactory. Studies initiated after the strike have confirmed the unsatisfactory distribution of fertilizer in irrigation water at several plantations. Fertilizer distribution was determined by the "inflow-outflow" method employing small flumes.

Extensive tests are under way at HC&S and Oahu Sugar to determine if aerial applications of granular fertilizers can result in increased yields through reduced amounts applied and through better distribution. The lowering costs of urea are accelerating interest in aerial fertilization of irrigated lands.

STUDIES CONTINUE ON FLUMES AND OUTLETS

Work on flumes and outlets was confined to investigation and exploratory design relative to the possibility of using injection molding of plastics to give a suitable flume outlet. The cost of an HSPA draw-down outlet can be substantially reduced by means of injection molding, assuming adequate quantities. Also, other shapes of outlets which might give satisfactory results and would require lower mold and unit costs have been investigated. Another consideration has been the possibility of using a plastic outlet to replace the outlets currently used in concrete flumes. An injection mold was made to make gates for the HSPA draw-down outlet.

FIELD LAYOUTS IMPORTANT FOR SURFACE IRRIGATION

This study by the Field Engineering Department has the over-all objective of recommending changes in irrigation layouts that would improve the working conditions for all mechanical operations. Also, there is the accepted possibility that irrigation performance might be increased. The effects on yield of radical deviation from what is now standard practice are being checked by the Agronomy Department.

There has been speculation for several years as to what could be accomplished with surface irrigation layouts to make them more compatible with mechanical operations. It was possible to initiate work on this project this year. As background data, a study was made of furrow slopes and some of the factors affecting slope. Representative samples of the fields at HC&S and Lihue were surveyed. Treatments included plant cane, with or without land smoothing and grading, and ratoon cane. This gave a picture of the results which are being obtained with the present standard systems and what might be accomplished with smoothing and grading. Also, some consideration was given to the minimum radii of curvature which could be negotiated by row-follow harvesting equipment, since production operation of this type of equipment requires better conditions than most machines.

The first detailed field test on this project was carried out in Lihue Field 34A. The objectives were to determine the effect of land smoothing on a furrow grade and the effect of using a variable guide furrow layout grade on irrigation furrows, and to estimate the cost of grading the field completely, thereby achieving a "perfect" surface irrigation layout.

The slope picture in the usual irrigation furrow layout was established and the influence of the land plane was noted. It is particularly effective in removing minor knolls and depressions and the irrigation and cultivation scars. Variable furrow grade, within allowable limits, was found to be a very effective means of achieving straighter lines and fewer short lines.

Along with this work on field layouts, an attempt was made to lay out furrow guide lines mechanically. An Ellis Contour-Liner was mounted on an Albee Model 1700 Rolligon tractor. Results were not encouraging because of the instability of the prime mover. The Ellis Contour-Liner was remounted on the

Figure 43. Soil and weeds are thrown out of level ditches by the attachment on the garden tractor.

flume pickup machine which is a light-duty prime mover with extended tracks. This machine was more stable and results were encouraging. This procedure will be compared with a standard procedure used for layout ahead of the planting machine.

In an effort to understand more thoroughly the problems involved in furrow layout, the procedures used at Olokele, McBryde, and Lihue for locating guide lines ahead of the planting machine were studied. Some refinement of procedure and standardization should result in some increase in accuracy and efficiency.

FIELD STRUCTURES FOR SURFACE IRRIGATION

Some results have been accomplished in calibrating the header gates used in aluminum flume lines so that flow into individual flumes may be spot-checked with reasonable accuracy. To date, one type of header gate has been calibrated and the results correlated with limited field data.

Several galvanized iron flumes, fabricated with the concrete flume cross-section and using the HSPA draw-down outlet, were made up for trial in concrete flume lines where the flume line is crossed by a harvesting road. The lighter sections of metal flume can be easily removed and more easily reinstalled after harvesting.

MECHANIZING LEVEL-DITCH CLEANING

Work has been initiated which should result in mechanizing the cleaning of level ditches. By starting with the least expensive unit, some success was achieved by using a garden tractor. A rotating disc mounted on the front of the Gravely tractor has been modified in order to attain the desired results (Figure 43). Preliminary findings are:

1. Relatively deep, narrow channels are difficult to work in.

2. Loose, unconsolidated material can be moved quite well, but little can be done in hard, consolidated materials.

3. Tall, lush-growing grasses can be handled reasonably well.

4. Rocks and rock layers are difficult and sometimes impossible to work in.

5. Direction of operation needs to be with the wind to avoid working in dirty conditions.

6. Continuous effort by the operator is necessary to control the tractor.

Some exploratory work has been accomplished on a different principle of moving the soil from within the ditch to the bank on either side.

LAND FORMING MAY IMPROVE SURFACE IRRIGATION

Work on land forming ties in directly with field layouts for surface irrigation. So far, this work has been limited to land smoothing, using a land plane along with a limited amount of grading. Since the work so far has been done on production areas, risk of jeopardizing production was not logical. When the effects on yield of major land forming in different types of soils have been determined, then maximum use can be made of this procedure to approach ideal layouts. Several field tests have been installed to show the influence on furrow slope of land smoothing with land planes.

The term "land forming" brings together a combination of practices which include land leveling, precision grading, land smoothing with land planes, subsoiling, deep tillage, filling of gullies, and grassing waterways. The control of water in an orderly manner made possible by those practices and procedures which alter the surface and subsurfaces of the field may lead to an increase in yields rather than to a decrease in yields following some exposure of subsoil.

PRELIMINARY ENGINEERING COST ANALYSIS OF OVERHEAD IRRIGATION SYSTEMS

This study was initiated to determine if there is irrigation equipment available or if equipment and a system could be devised which would compete on an over-all basis with the standard surface irrigation systems. All possible existing systems and equipment have been investigated. Systems and equipment which showed some promise have been analyzed to estimate equipment costs, costs of operation, and manpower requirements. Several ideas for new types of equipment and new systems have also been investigated.

Several boom-type units which theoretically would allow for low-pressure application in windy conditions have been investigated.

1. Automatic travelling spray rig: Self-propelled spray booms mounted on a four-wheel dolly would be pulled back and forth and guided by an endless wire rope stretched between anchor sheaves. Power would be provided by a water motor mounted on the dolly assembly. The unit would move back and forth over the staked-out area until the total amount of water required had been applied.

2. Move-stop rig with a coverage of one acre: A lattice-type boom assembly, measuring 200 feet on each side, would be parked over the area to be irrigated. Water from 440 spray nozzles would fall continuously on the area until the total application had been applied.

3. Travelling truck-mounted booms: Two booms would be mounted on a truck which would move back and forth over the area until the required total application had been applied. This unit would require an operator.

4. Move-stop rig with Pomona booms: Two Pomona square sprinkler revolving booms would be mounted on a carriage assembly and parked over the area. Water from the two revolving booms would drop on the area until the required application had been applied.

Preliminary estimates indicated excessively high costs per acre per year. The possibilities of this type of equipment are contingent largely on design ingenuity to reduce equipment costs and to find ways of increasing soil intake rates. This equipment offers field layout potential for optimum mechanization of all production and harvesting operations.

A survey of the different types of equipment available from manufacturers resulted in the conclusion that the semi-permanent system has possibilities. Semi-permanent describes a system where the laterals are laid on top of the ground and removed ahead of harvesting. A comparison of equipment costs and coverage in windy conditions recommended the 30x50 spacing, using relatively small sprinklers (3 to 12 gpm.). On the basis of available equipment, the minimum total cost of irrigating with this type of system was estimated at $141.00 per acre per year. In all of this work, one question which continued to arise was the actual and complete cost of the present standard surface irrigation systems. This led the Industrial Engineer to initiate a study on surface irrigation costs, now in progress, which will give a basis for comparison with new systems of irrigation.

Irrigation equipment manufacturers have been working on ways and means of reducing the cost of the 30x50 system of semi-permanent irrigation. One result of this work is the Shur-Rane Sequa-Matic system which is discussed below. Another new development is the Farmland "Irromatic" system which uses even smaller sprinklers and a very low rate of application. The effect of wind on this latter system is to be determined.

Figure 44. Pomona square sprinkler rotary boom being tested.

POMONA SQUARE SPRINKLER TESTED

The Pomona Irrigation Equipment Company had done some work on a revolving boom which would sprinkle a square pattern. A cooperative arrangement was set up whereby they fabricated a new boom unit. Their initial tests of this assembly were not encouraging. Since they were not in a position to proceed on this development, the equipment was shipped to Honolulu for testing and for development if results justified (Figure 44). The initial tests here with this equipment showed a uniformity coefficient of 71 per cent in four mph. winds and a water loss of about 12.6 per cent. These values are less satisfactory than those obtained with conventional rotating sprinklers. Nozzling of the boom to reduce spray and improvement of the corner sprinkle nozzle assembly are areas for major improvement. If the over-all picture for overhead irrigation indicates the need or use of such a rotating boom assembly, substantial improvement can be made.

USE OF STANDARD OVERHEAD IRRIGATION EQUIPMENT

This project was set up at the time a plantation had approximately 200 acres of cane being irrigated by an Ames tow-line system. On a cooperative basis, some improvement of the equipment which was giving trouble with accelerated use, was accomplished. The most recent development in this area is supplemental irrigation being tried by Kilauea using Ames rotary boom units. There are tentative plans for cooperating on the determination of uniformity of distribution and water losses with this equipment.

DISTRIBUTION TESTS ON SMALL SPRINKLERS

The potential of a semi-permanent irrigation system using smaller-size sprinklers prompted a look at the requirements for such a system. Investigation showed that there were no performance figures for the small-size sprinklers in winds above several miles an hour. Tests were set up to determine uniformity coefficients for small sprinklers (three to 12 gallons per minute) as a function of one or more of the following variables: sprinkler make, model, height and spacing, nozzle size, nozzle type, pressure at nozzle, wind direction and wind speed. The work was also set up to characterize water loss of the small sprinklers as a function of the variable expected to effect the coefficient of uniformity.

The completed and analyzed tests have established general trends. Relative to the uniformity coefficient, the following points were established:

1. No variation could be attributed to different makes or models.

2. Uniformity increased with increased sprinkler height.

3. As the area covered by a single sprinkler increased, the uniformity of application increased.

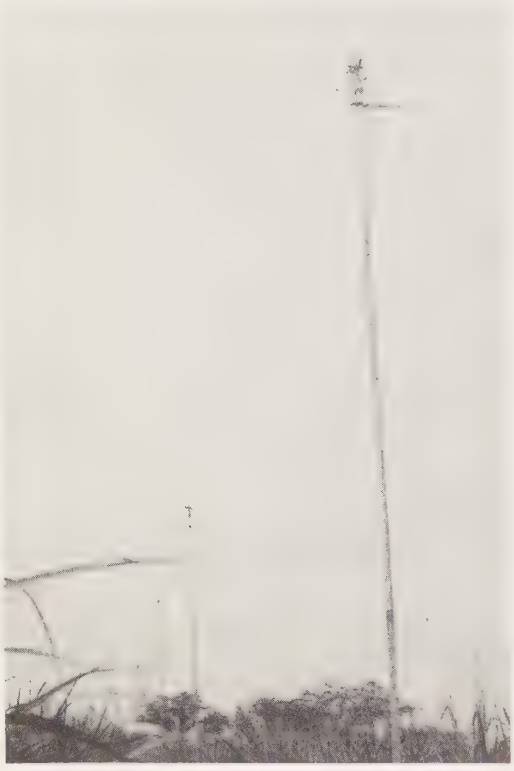


Figure 45. A variation of the Shur-Rane Sequa-Matic System is being tried for stabilizing 12-foot risers.

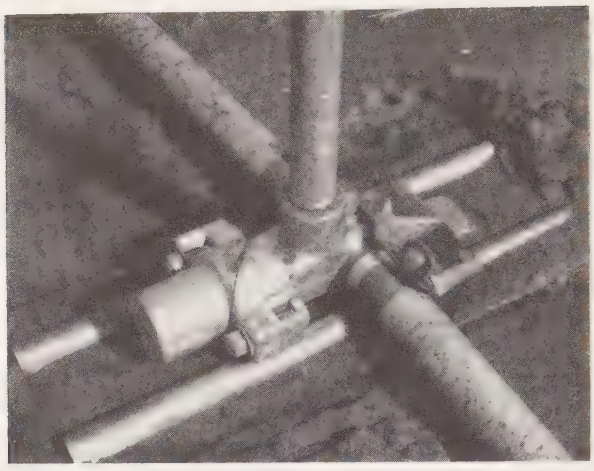


Figure 46. Valve on lateral at base of riser in Shur-Rane Sequa-Matic System.

4. Uniformity increased with pressure increase.

5. Uniformity was only slightly affected by nozzle size.

6. Plain circular nozzles gave better uniformity than slotted nozzles for higher winds.

7. The greatest uniformity occurred when the winds were perpendicular to the long dimension of the pattern.

8. Uniformity decreased with increased wind speed.

With regard to water loss, the following trends were established:

1. Variation could not be attributed to make or model.

2. Loss increased with increase of sprinkler height.

3. Loss increased with pressure up to about 40 psi, followed by a decrease.

4. No variation in loss could be attributed to nozzle size or type.

5. Loss increased with wind speed increase.

Estimates for specific conditions can be made using accumulated and compiled test data.

SEMI-PERMANENT OVERHEAD IRRIGATION UNDERGOES FIELD TRIALS

A cooperative installation using Shur-Rane Sequa-Matic equipment has been made as a means of testing this equipment for the irrigation of sugar cane since it offers a possibility of reduced equipment cost (Figures 45 and 46). This test will also serve to determine more conclusively the potential and adaptability of a semi-permanent overhead irrigation system for watering sugar cane.

In laying out the installation, special attention was given to use of machinery for planting, fertilization, weed control, and removal of the equipment before harvest. Also, the possibility of leaving the equipment in during harvest is being investigated.

This installation has been in operation at HC&S for several months. While there have been difficulties, the causes have been determinable and are being corrected. This type of equipment and system offer the ultimate in push-button irrigation.

MECHANIZATION

SEED CANE HARVESTER PROVES SUCCESSFUL

The second cutting assembly, a design of which was aimed at tolerating more lodged cane, was initially field-tested in October 1958. The stalks are cut off at the ground after being engaged by gathering chains which extend to the ground. Simultaneously, the stalks are topped and engaged by a pair of corrugated belt lay-down chains. The stalks are laid down continuously in a 24-inch wide conveyor and cut into approximately 18-inch lengths by a cross-flow type of cutter. A simplified design of the cross-flow cutter gave satisfactory results. Quality of cuts was improved by a grooved and timed roll against which the cutting occurs.

The major developments required were additions to facilitate handling the older, heavier-growth cane. The changes included a second pair of gathering chains and a feed roll in the conveyor between the lay-down chains and the cross-flow cutter. The major continuing developments are better detrashing and further refinement of the quality of cuts.

The second cutting assembly was found to give a more satisfactory result over a greater range of conditions than the first cutting assembly which conveyed the stalks into the machine in the erect position. Preliminary conclusions on the second machine are as follows:

1. Operation in partially recumbent cane is satisfactory.

2. Maximum stalk length for satisfactory operation is about nine feet.

3. Seedpiece lengths are from 15 to 22 inches with a few shorts and very few long pieces.

4. Density in bulk bins is up to 18.5 pounds per cubic foot.

5. The machine is set up to operate at 1.4 miles per hour ground speed. The cutting rate is approximately 20 tons per hour while cutting.

6. The planting rate, using machine-cut seed, has been as good as when using hand-cut seed.

A preliminary check of seed quality in 41-3340 cane gave the following results: by weight, seedpieces with no damage, 67.7 per cent; seedpieces with some damage, but with one or more good eyes, 17.3 per cent; unusable, fully damaged seedpieces, 1.7 per cent; opala, 13.3 per cent. In summation, 85 per

Figure 47. Seed cane harvester in operation filling bulk seed bin.

Figure 48. Side view of seed cane harvester showing gathering, cutting assembly.

cent of the weight of the material in the seed bin can be considered good net weight seed.

This experimental machine has been in semi-production operation at Kohala Sugar Company and the use of a seed harvester has become part of their planting system (Figures 47 and 48).

The weaknesses which have shown up in this operation have contributed to design improvement. Kohala is having a machine built on a TD-15, the design of which is based on the design and development of the original machine plus a storage transload conveyor instead of a rack for loading bulk bins. One design improvement is to let the weight of the storage conveyor assembly counterbalance part of the weight of the cutting conveyor assembly, thereby reducing the load on the outboard wheel.

The addition of the storage transload conveyor increases the cost of the seed harvester but makes possible a lower over-all cost for planting equipment.

The two-ton capacity storage transload conveyor was devised as part of a system originated by Kohala which substantially reduces the capital cost of a complete seed-cutting and handling system. The cut seed will be loaded directly into a four-compartment, water-tight truck body. The hot-water treatment will be accomplished in the truck body. Each compartment will fill a bulk bin at the planting field for forklift transfer to the planting machine. One fringe benefit of this system is eliminating a fork-lift in the seed-cutting area, which has been a principal source of damage in the seed cane area.

Design changes and parts have been made to convert the experimental flat culture machine for cutting cane in furrows. On the basis of test operation and development for furrow irrigated cane, drawings will be made available.

TWO-WAY CANE PLANTER DESIGNED

Interest was indicated for a means of planting unirrigated cane completely to the field edge at both ends of the lines. Such a system could eliminate most of the hand work now required at the ends.

The results specified could be accomplished in two different ways: a design incorporating the use of a turntable, or a double-ended arrangement. Exploratory design showed that the minimum two-way planter would be the double-ended arrangement. This general design would give a two-way planter of minimum cost, minimum weight, and minimum maintenance.

The exploratory design used a D6-size tractor with a 9-foot gauge and a 7-roller track frame. The operator was seated either sideways or on a reversible seat in the middle of the machine. The seed bin on each side would be open at both ends and provided with a movable conveyor floor which could be shifted in either direction by the seed droppers. There would be furrowing plows at each end and seats would be

located at each end for the seed droppers. The machine would pull up to the end of the line, the plows in use would be lifted and the plows on the forward end dropped, the seed droppers would shift ends, then the crew would plant back from the end and connect up with the two lines which had just been planted. The operator would then reverse the machine and angle over into position for the next two lines which would start from the edge of the field. The capacity of each seed bin would be approximately 170 cubic feet, and a 570-gallon tank was provided for aqua ammonia or liquid fertilizer.

Such a machine should do almost no damage along the edges of the field and should plant the lines completely. A planter arrangement such as this should also have merit in the planting of irrigated cane, particularly with the herringbone system and the use of concrete flumes.

FIELD ROAD REPLANT ATTACHMENT ON LINE RESHAPER

The results of field experiments in relation to the value of replant have stimulated considerable interest in ways of accomplishing the reduced replant required. Work is in progress at Oahu Sugar relative to heavy replant in field roads immediately after line reshaping and before the first irrigation. The possibility is being tested that this replant may be all that will be required for normal conditions. A staff member at Oahu Sugar suggested the possibility of accomplishing the furrowing out for the replant by an attachment on each line reshaper assembly. This has been accomplished on a cooperative basis and is now being tested (Figure 49). The possibility of also carrying the seed on the line reshaper prime mover is being considered.

Several possibilities were considered for a combination infield transport and replant machine which would not do excessive damage to the reshaped lines. The exploratory design and estimated economics of such equipment were not encouraging.

CANE PUSHED BACK MECHANICALLY

As a means of mechanically pushing cane, exploratory design recommended testing a powered corrugated belt for pushing the cane perpendicular to the direction of travel. An assembly, designed to be mounted on a D-4 tractor, consisted of a nine-foot bar equipped with a powered corrugated belt six inches wide attached to a single strand of conveyor chain (Figure 50). The forward section of the belt which contacts the cane is set at an angle of 60° to the direction of travel. The belt speed is adjusted to forward travel speeds so that the cane is laid over a 90° angle to the direction of travel. The bar assembly is fully adjustable by means of hydraulic cylinders, from a position flat on the ground to a vertical position for transport. Results indicate that skillful use of this principle can result in less breakage than is experienced with hand pushback. Up to six miles of field edge has been pushed during an eight-hour shift. Maximum pushing speed is about 1.6 mph.

Figure 49. Line reshaper furrow attachment whereby reshaper can leave replant furrows for field road replant. (Cooperative with Oahu Sugar Company.)

Kilauea has adopted the use of one of these pushback bar assemblies which is attached to an extension frame whereby the operator can reach out an additional five feet across narrow ditches or into more inaccessible areas than is possible with a standard type of mounting. HC&S has increased the versatility of this principle for pushback by putting a bar on a small

Figure 50. The cane pushback is equipped with a corrugated belt to control cane.

track-type tractor. The bar assembly pushes to the right the cane which is located directly ahead of the tractor; therefore, the unit can work in the field along ditches. With this type of unit, cane in almost any location can be pushed back mechanically.

PROTECTIVE COVERINGS FOR FIELD EQUIPMENT

The corrosion of fertilizer and weed spraying equipment, and the free flow of fertilizer in hoppers, continue to be areas for improvement. The pilot liquid fertilizer mixing plant has been used as a means of testing different protective coating materials. Seven different materials have been tested by painting strips of each, both inside and outside of the fertilizer mixing tank. The seven materials are: 1) "fluid-film" provided by the Chemistry Department; 2) Metaz plus ZRC, a zinc base primer and epoxy base finish; 3) Pliogard, a rubber base coating; 4) liquid Neoprene; 5) polyester resin; 6) Duraflor, an epoxy resin; and 7) Tenaco. Strips of bare metal were left as control. The internal surface was exposed to the aqua ammonia and muriate of potash mixture. The external surface was exposed to weathering and the splashing of the liquid fertilizer.

After 19 months, the internal surface coatings which were in the best condition are Duraflor and the "fluid film". The Duraflor was in excellent condition and can be considered the best internal protective coating tested. On the external surface tests, Duraflor was the only material which showed promise and its condition was classified as excellent.

Teflon, both as a sprayable material and in thin sheets, has been tried in fertilizer bins. None of the tests where the Teflon was sprayed on showed encouraging results. Sheet Teflon used inside fertilizer bins has given satisfactory results. Progress is being made in the art of cementing sheet Teflon to metal surfaces, which may make the use of thin sheets more attractive.

Some exploratory work in the use of resins as protective coatings and fabrication materials has been initiated. A fiber glass tray installed in the mixing tank of the liquid fertilizer pilot plant has shown no corrosion. The fiber glass tray also reduced the weight to eight pounds as compared to 52 pounds for the steel tray.

Because of the appearance of Duraflor after 12 months of testing, the herbicide applicator was painted with two coats of this material. Several spots started to chip and peel after several months. Examination showed that the metal surfaces of these areas had not been properly prepared prior to applying the Duraflor. This emphasizes the necessity of the proper preparation of the surface being painted. Weathering and herbicide corrosion have had no effect on the Duraflor which had been properly applied.

Figure 51. Raking liliko, following ground-cutting by knife, between tracks and ahead of tractor center.

LIQUID FERTILIZER INJECTION

Experimental use of high-pressure fumigant injection in the pineapple industry suggested the possibility of injecting a liquid fertilizer such as aqua ammonia. The possibility has been explored that a pump and valve, developed for some other high-pressure liquid use, could be used for the injection of liquid fertilizer in the quantities required. Results to date show one available type of pump which may take care of the pumping problem. If the cost of available usable equipment, the cost of special equipment required, and the horsepower requirements all look encouraging, work can be initiated on a project basis.

NEW APPROACH TO LILIKO PICKUP ON WET SOILS

The experimental 10-foot-wide star-wheel liliko pickup unit has continued in operation with dry conditions. An intensive development program was pursued with this unit in an attempt to make it function satisfactorily in conditions of damp, sticky soil. The final conclusion was that a pickup principle which picks up sticky soil effectively could not be considered satisfactory. The principles which might be effective over a range of conditions for the pickup of loose liliko were reviewed.

As a result of this review, a spring-tine reel pickup is being tested. The pickup tine reel which has been assembled has a 10-inch pitch diameter with four bars of spring tines. A roller on a short lever arm at one end of each tine bar assembly rolls in a guide, which can be changed, to determine if spring tines on a small-diameter revolving drum or reel can be made to pick up loose pieces of short cane. The over-all pickup width is five and one-half feet. The pieces of cane picked up will be dropped onto a short conveyor which will accumulate the cane in a small bottom-dump hopper. The entire assembly will be carried on a forklift as a means for field testing and experimentation. The pickup reel will be gauged by a wheel at each end. Field testing of this principle is being initiated.

LILIKO CUT-WINDROW PRINCIPLE ABANDONED

During the past year, changes were made on the liliko cut-windrow machine several times in an attempt to attain a gathering-conveying action which would deliver short cane from a ground-cutting knife into the conveyor dump hopper. While this goal was attained to limited degree, rocks and stools were en-

gaged as effectively as cane stalks, blocking the conveyor and rendering it inoperative until cleared.

Tests run indicated that this experimental unit could pick up approximately 50 per cent of the liliko following grab-harvesting. The only really effective development was the ground-cutting knife. Because of this, the pickup-elevating conveyor approach to the problem was abandoned as being too inefficient and impractical in principle. The gathering conveyor assembly and the storage hopper were removed in order to try other approaches to the problem.

LILIKO CUT RAKE TESTED

After removal of the gathering-conveying assembly and the storage hopper from the liliko cut-windrow machine, the prime mover was operated with the rotary ground cutting knife as a liliko cut-only unit. This was an effective means for cutting attached liliko. The major problem in using a rotary free-cutting knife for cutting liliko is that most of the cutting needs to be at the pre-harvest furrow bottom and the power consumption is high. For most conditions, 35 to 45 hp. must be available for the operation of the ground-cutting knife.

As a means of accumulating the loose and cut liliko during the ground cutting, a set of light tines was mounted several feet back of the cutting knife. In the first arrangement, the tines went up and down with the knife assembly. Operation showed that the tine assembly and the knife had to be gauged individually. The rigid tines were replaced by spring tines so as to give some individual adjustment of working height. With the rake and the cutting knife closely associated, there continued to be interference between the two operations. The next arrangement tried was to leave the ground knife in its existing position forward of the center of the prime mover and a spring tine rake assembly was mounted on the rear of the prime mover (Figure 51). This arrangement is the most effective one tried and is a practical means for cutting and accumulating liliko where a great deal of the liliko is still attached to the stools. The disadvantage to this arrangement is that the rake is on the rear of the prime mover and the accumulated cane is not pushed into the windrow of harvest cane for easy loading. To have both the ground cutting and the raking at the front of the prime mover would give certain advantages, but the preliminary work indicates that some quality of work would be sacrificed.

CUT-WINDROW (SIDE-MOUNTED) HARVESTER

The results with this side-mounted cut-windrow machine have continued to range from very good to very poor, a range largely the result of field conditions, state of development of principles and mechanisms, supervision, maintenance, adjustments, and the training and skill of the operators. The greatest development problem has continued to be the gradual accumulation of soil and leaf trash on the deck of the elevating conveyor under damp, sticky conditions. By cutting too high, the operator can keep the deck cleaner with unfavorable conditions, but this high cutting is a major cause of liliko. This problem is still being pursued with the indication that there can be improvement even though a complete solution to the problem on a practical basis is not foreseeable.

Several experimental changes were made on the HSPA-owned cut-pickup-elevating conveyor assembly and the assembly was kept in production operation. Results indicate the advisability of carrying two of the seven experimental changes over into production operation: the addition of a pickup tine on the inside of the conveyor, and the use of a drum-type of reel in lieu of the pickup reel with verticalized tines.

Hacienda Cartavio has purchased a third machine which was fabricated by a Honolulu shop.

CUTTER TRANSPORT HARVESTER

The drawings on the revised design of this type of machine have been completed, reviewed in detail, and re-revised. A brief description of this machine was covered in the last report. This revised design assured a substantial reduction in first cost, weight, and maintenance, as compared to the existing machines. The elimination of all counter shafts and of all chain drives, except for two short drives, by the use of oil motor power, represents a potentially major improvement. However, when major changes are made in the design of a machine, at least one season's operation is essential before conclusions can be drawn. The first machine built from these drawings would be considered a prototype machine in the trade.

TWO-WAY CUT-LOAD HARVESTER READY FOR SPECIAL TESTS

Progress has continued on the development of the two-way cut-load harvester. The progress has not been as spectacular as hoped for, but all indications are that the design for a practical machine of this principle is being determined. This machine has always been set

up for and operated in furrow-irrigated cane. Not having arrived at satisfactory automatic or semi-automatic furrow-follow, has detracted somewhat from the progress in other areas.

Early this year, one conveyor assembly was remounted. The lift-pivot point for the conveyor assembly was shifted vertically from six feet to one foot above the furrow. It was also shifted forward to where the total weight was balanced on the pivot except for a light load on the gauge wheels. The side swing of the conveyor was retained for furrow-follow, and the ground knife was located at the center of the conveyor assembly to equalize frontal resistance. The number of elevating conveyor chains were reduced from seven to six and pickup tines were reduced from five to four.

Field testing of these changes showed that considerable advantage had been gained in relocating the pivot point of the conveyor. The gauge wheels were reasonably effective in gauging the cutting height and there was very little tendency for the conveyor to nose in. However, the gauge wheels were still not effective enough for the lateral control of the conveyor. The gauge wheels did not hold the cut-pickup assembly in the furrow except under ideal conditions. The location of the ground knife in the center of the conveyor and the use of four pickup tines gave limited beneficial results. The two additional pickup tines reduced liliko, but the arrangement to equalize frontal resistance had little effect on the operation.

As a possible means of making the furrow-follow more effective, the gauge wheel assembly was pulled from a point just behind the ground knife box. Limit switches were installed in such a way that when the gauge wheel assembly shifted because of side pressure, a solenoid valve operated a hydraulic cylinder so as to recenter the conveyor on the furrow. Field testing showed no positive results for the type of equipment used.

As a means for the gauge wheels to have a more positive control on cutting height, an adjustable pressure switch was inserted in the pressure line to the oil motor which drives the ground knife. Field testing showed this procedure to be an effective means for positive control of cutting height. The surge of pressure which indicates that the knife is cutting too low closes a switch which causes the ground cutting knife to be raised until pressure drops to normal. If the pressure drops too low, which indicates high cutting, the other switch is closed and the conveyor is lowered. Modification of this equipment is necessary in order to reduce hunting.

Quality of work accomplished by side trim knives has been a problem on some of the production cut-windrow machines. This machine has always been equipped with free-cutting side trim knives and in some conditions, particularly at slow cutting speeds, the cuts have been ragged. The side trim knife on the conveyor being tested was changed to the four-blade, shear plate cutting knife and was located 12 inches ahead of the previous knife location. It was demonstrated that by having the knife located properly, knife speed synchronized approximately with travel speed, and with the knives streamlined, clean cuts with no recutting were possible.

The major work on this machine is intended to compare cane harvested by this type of machine with rake-harvested cane. The length of cutting by the cross-flow cutter is being reduced from 36 inches to 18 inches of the flow. A blast of air is being added at the top end of the elevating conveyor to accomplish some detrashing after the cane has been cut by the cross-flow cutter. A second blast of air was incorporated with a light fluffing drum and a deflector which are being added to the discharge end of the cross-load conveyor. The side swing feature has been taken out of this conveyor assembly so as to have one less variable in the test work. As time permits, the cutting height control on the test conveyor can be improved. Work relative to automatic furrow-follow can be accomplished on the other conveyor assembly.

In line with cost reduction and simplification of the machine, air shuttle valves have been installed to replace the previous mechanism for shifting the prime mover controls from one operator to the other. Four of these small shuttle valves have replaced 10 globe valves, two air cylinders, and 20 pieces of air hose, plus the electrical wiring to actuate the air cylinder controls.

CUT-THROW EXPERIMENTAL HARVESTER UNDERGOES PRELIMINARY TRIALS

Considerable interest has continued in the possibility of a way to improve harvesting which would require minimum changes of cultural practices, and require capital, maintenance, supervision, and operator training comparable to that of the push-rake system. There was doubt that the principles being used for picking up and handling cane would result in a machine or machines which would have wide enough

Figure 52. Preliminary test operation of the experimental direct cut-throw harvester.

acceptance in the industry. These principles were arrived at by elimination and experimentation during the period from 1946 to 1951. It became advisable to re-examine all possible ideas and principles for cutting and picking up cane which might result in a more acceptable harvester.

A potential means of reducing machine weight and cost would be to eliminate all conveyors. If the cane were immediately cut into short lengths, conveyor sizes and costs would be reduced but not eliminated. If the cane could be cut fine enough to be thrown or blown into transports, conveyors would be entirely eliminated.

The re-examination of ideas and principles pointed to the advisability of a complete investigation of the vertical rotation flail-type knife arrangement or principle, which had been developed for forage crop harvesting. On the basis of the operation of two different types of 24-inch tip diameter forage harvesters, it was recommended that an experimental unit of a larger size be designed and built so as to test thoroughly this principle for cutting and handling cane. The cut-throw type of machine is the simplest conceivable method for cutting cane at the point of growth and throwing it directly into a transport. This was selected as the starting point.

A 48-inch tip diameter six-foot-wide cut unit was designed to be sidemounted on a prime mover for field test operation. There is enough built-in flexibility to operate over a wide range of speeds and field conditions. The knife rotor assembly is driven by oil motors, and pressure and oil flow recording equipment was procured to determine power consumption (Figure 52). The objective of this project is to obtain data in the following areas:

1. The maximum cane cutting tonnage rate of an estimated size unit for sugar cane.
2. The power requirements when working under actual field conditions.
3. The liliko rate with respect to whole, uncut cane and finely cut cane particles left on the ground.
4. The optimum particle size and load density.
5. Amount of soil pickup with acceptable liliko.
6. Optimum design of flail-type knives to cut sugar cane.
7. Optimum arrangement of knives for both irrigated and unirrigated cane.
8. Optimum throw of chopped cane from rotor to transport.
9. Economic influence of chopped cane on all major subsequent operations in the field and in the mill.
10. The feasibility of associating this type of harvester with diffusion and cane pumping.

Two rotors are available whereby there can be two, three, four, six or eight rows of knives. Two farm-type self-unloading wagons have been procured to accumulate and transport the material harvested.

Initial operation took place at HC&S, showing a

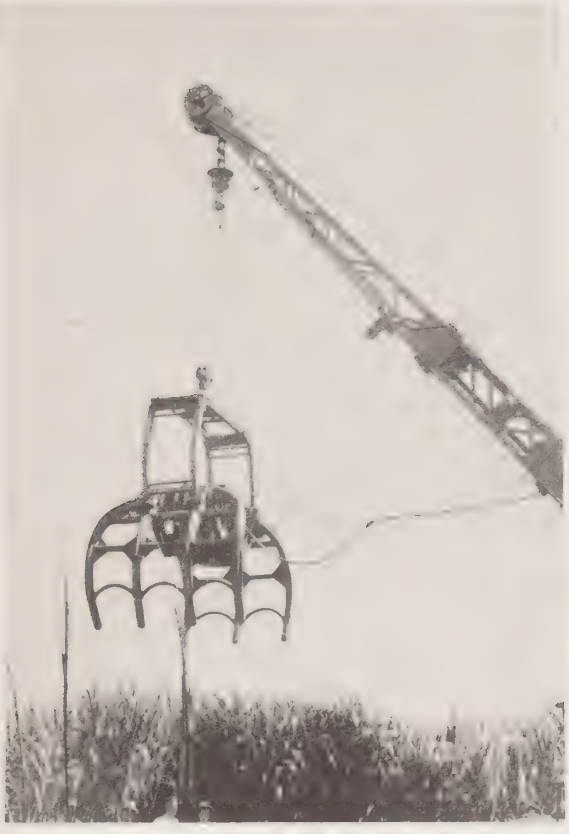


Figure 53. Load cell is attached to lift line of the hydraulic remote reading scale.

Figure 54. The scale of the hydraulic weigher is located in this crane cab.

substantial consumption of power in producing wind and particles quite small in size. Differently shaped and fewer knives have contributed to larger particle size. Further work on blades is in progress and additional available power is being added to the rotor. The results of the operation are approaching the point where semi-production can be initiated and the accumulation of data can be started.

WEIGHING FIELD EXPERIMENTAL CANE

The initial testing of the hydraulic remote-reading scale, procured from Martin-Decker and installed on the Waipio Substation hydraulic grab, gave excessive error (Figures 53 and 54). Discussion with the manufacturer revealed that this type of equipment was sensitive to differences of hydrostatic head in the hydraulic line and also sensitive to flexing or stretching of the hydraulic line. As a means of trying the equipment without these possibilities for error, the load cell was attached to the top end of the boom and the wire rope lift line passed through a sheave installed on the headpiece of the grab. Since this reduced the load on the cell to one-half the actual load, the dial reading could be multiplied by two. Subsequent tests have shown a high degree of accuracy as long as the reading each time is taken with the grab at approximately the same distance above the ground. The final report shows that this equipment has been accepted by the Waipio Substation as a means of weighing field experimental cane. This equipment will be exchanged for a unit of less capacity and with a special dial for giving a direct reading of the load in the grab.

HARVESTED CANE CORE SAMPLER READY FOR TESTING

A means to expedite and reduce the cost of sampling harvested cane for the determination of tare and juice quality was needed. Exploratory design showed that a unit which might accomplish this was mechanically feasible. The stationary machine which has been

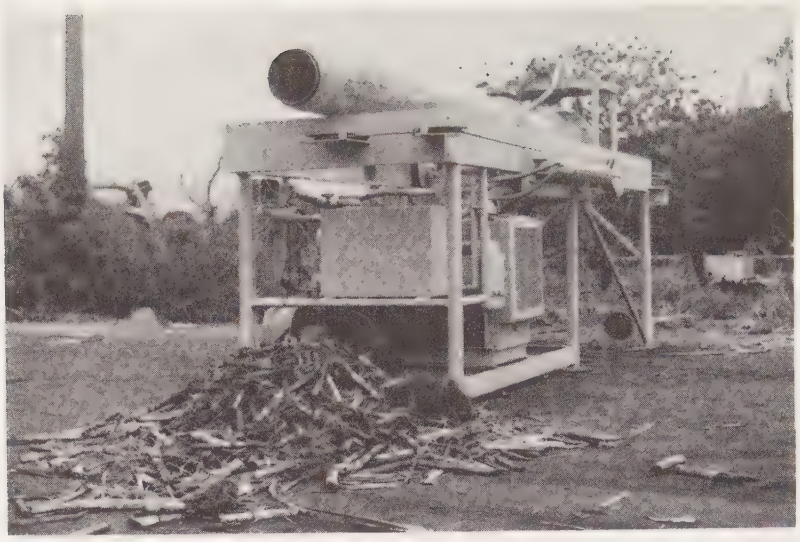


Figure 55. Core sampler for removing samples 10 inches in diameter from load of harvest cane.

designed and fabricated should remove a core sample 10 inches in diameter by six feet long from a load of cane.

The machine consists essentially of a 10-inch I.D. tube 14 feet long which is powered to rotate inside an 11-inch I.D. outer tube (Figure 55). The outer tube is mounted on a carriage assembly which rolls on a track and is controlled by a hydraulic cylinder. The end of each tube is removable so that different types of teeth may be tried for cutting the 10-inch diameter core as the tube assembly is forced into the load of cane from the side. The track of the carriage assembly allows for seven and one-half feet of travel; so it is assumed that a core at least six feet long can be removed from the load of cane.

This unit is ready for initial testing.

ORGANIC CHEMISTRY

INTEREST IN CANE WAX EVALUATION CONTINUES

At the suggestion of the S. C. Johnson and Son, Inc. research group, further experimental work has been done on specific aspects of the cane cleaner wash water scum wax.

Extraction of average crude wax (about 80 to 85 per cent hard wax) on air-dried scums from the Ewa hydroseparator has been about four to five per cent, with no apparent differences when samples were collected at different times during the week or during the day. Storage of dried scums is excellent; a fermented odor develops in wet scums within one week due to residual sugar content. In an attempt to measure biological decomposition of the wax of stored wet samples, comparisons were made of melting points of crude waxes, acid number and infrared spectrophotometric curves between fresh extracted wax and the extracted stored samples. No difference in wax odor, melting points (57° to 66° C.), acid number (31 to 35), or qualitative infrared inspection was found.

BAGASSE PITH AS AN ABSORBENT FOR LIQUID AND WETTABLE POWDER HERBICIDES

There are local uses for granular herbicides, particularly for brush control by airplane, but because of the high cost of shipping clay adsorbents, little attempt has been made to use the granular forms. No suitable local clays have been developed for this purpose. Bagasse pith provides a possible absorbent for liquids because of its high absorptive capacity, even for oil-soluble liquids, and because of its availability and low cost. A major objection to its use is its low bulk density which requires large volumes and does not supply the weight which may be needed to prevent drift of the particles by the wind. Even so, drift should be less than with water or oil sprays or powder suspensions.

The normal mill moisture content of the pith (40 to 45 per cent) makes it possible to absorb the wettable powder pre-emergence chemicals on the pith particles.

Undried mill pith will absorb three to five times its weight of a 2,4-D or 2,4,5-T amine liquid concentrate without any appearance of excess liquid. The same is true for the 2,4-D and 2,4,5-T esters. The products are damp to the touch but completely friable, and could be spread by dry-dusting tractor techniques, by hand or by plane. The treated pith does not normally adhere to vegetation; its value then will be principally for pre-emergence application. Approximately one-third of a pound of 2,4-D or 2,4,5-T can be absorbed on one pound of the final product. This would require about a 12-pound application per acre. This pith-herbicide concentrate can be mixed with fresh untreated pith for greater dilution of the chemical.

BAGASSE PARTICLE BOARDS TO BE TESTED

Arrangements are being made with a Mainland concern to prepare and test large-sized bagasse particle boards using commercial toluene diisocyanate as the binding agent. This will permit an evaluation of the characteristics of particle boards made with resinous-type binding agents.

LEVULINIC ACID FROM CANE BY-PRODUCTS

Preliminary research was carried out to study the process of converting carbohydrate wastes to levulinic acid. Bagasse and molasses are available as possible raw materials. The work reported here was performed using sucrose as a model compound. Conversion of the sucrose with refluxing 15 per cent hydrochloric acid yielded 60 per cent of the theoretical yield of levulinic acid. Pressure digestion with sulfuric acid has been reported to yield a maximum of 70 per cent of theoretical. The theoretical yield is 67.8 per cent on sucrose.

Solvent extraction of the levulinic acid from the reaction mixture was attempted with ethyl acetate, diethyl ether and methyl isobutyl ketone. None was completely satisfactory. Levulinic acid is extremely water-soluble, as are its salts.

No large-scale use for levulinic acid has become apparent during the year.

TILLAGE

SOIL STUDIES SHED LIGHT ON TILLAGE PRACTICES

Agronomic investigations during 1959 have been limited to four phases: (1) effect of deep tillage-phosphate placement on sugar-cane root development; (2) distintegration tendency of buried soil lumps containing cane fiber and trash; (3) effect on subsequent cane development of trash burial by plowing; (4) further evaluation of the disc harrow as a secondary tillage implement.

Hydrol humic latosols and the humic latosols investigated showed deep root development despite shallow tillage and low available phosphorus in the subsoil (Figure 56). Deep placement of phosphate did not result in any visible evidence of improved cane root development at any depth within the first eight months of growth. There is little room for improvement in the excellent root system developing in these soils. From field and laboratory evidence, it appears that, as long as some roots can pick up phosphate and translocate it to other parts of the plant, adequate root systems develop in these Great Soil Groups.

Mixtures of soil and cane fiber and of soil and cane trash were compacted into cylinders and buried in a cane field during 1956. Figure 57 shows one of these as it was being exhumed from a cane field several years later. In this particular study, a Lahaina silty clay surface soil with additions of one per cent and 10 per cent organic matter (by weight) were compacted to 95 pounds per cubic foot, the denseness at which cane roots fail to penetrate this particular soil. Cane roots did fail to penetrate the compacted soil mixture and, when the cylinders were broken open, the cane fibers, or particles of cane trash, appeared fresh. Adequate soil moisture and fertilizers were added to the mixture to allow ideal conditions for micro-organic and cane root growth, but decomposition of the organic matter was not detected: the soil contained about six per cent "natural" organic matter and, following the test, all of the added cane products

Figure 56. Root development is shown in a Hilo silty clay soil, moldboard-plowed to a depth of 15 inches, and with 1000 pounds of raw rock incorporated in the top eight inches with a rotary hoe after plowing. The cane is eight months of age.

Figure 57. A cylinder of a soil, mixed with one per cent ground trash and compacted to 95 pounds per cubic foot, was dug up after being buried in a cane field for two years. Roots failed to penetrate the soil cylinder and the added trash had not disintegrated during this period.

were accounted for within the cylinders. Exceptions were noted in the cylinders to which 10 per cent cane products were added where mixing was poor and pockets of the organic material were exposed. Indications are that if a soil is compressed critically, even though it is broken up mechanically, the lumps, if buried below the zone of evaporation, will not loosen or mellow in two to four years.

Moldboard plows are well recognized as tillage implements capable of inverting a tilled horizon or burying surface organic material. In the tilled horizon, organic material is often buried in large pockets and these have been suspected as a possible source of poor cane development. However, recent investigations in low humic latosols under an irrigated cane crop showed no detrimental physical effects from the large "pockets" of buried trash (Figure 58). Under the moisture and temperature conditions existing in these permeable soils, decomposition was fairly rapid and, although evidence could be found which indicated the location of about half of the trash pockets, root growth was fairly uniform throughout the tilled profile and cane growth appeared equal to that found in plots in which trash was not plowed in.

During the past several years, the disc harrow has been evaluated as a harrowing implement and as a subsurface compacting tool. Recent studies have indicated that serious recompaction is not usually produced by tractor and harrow operations on low humic latosols during the summer months and even follow-

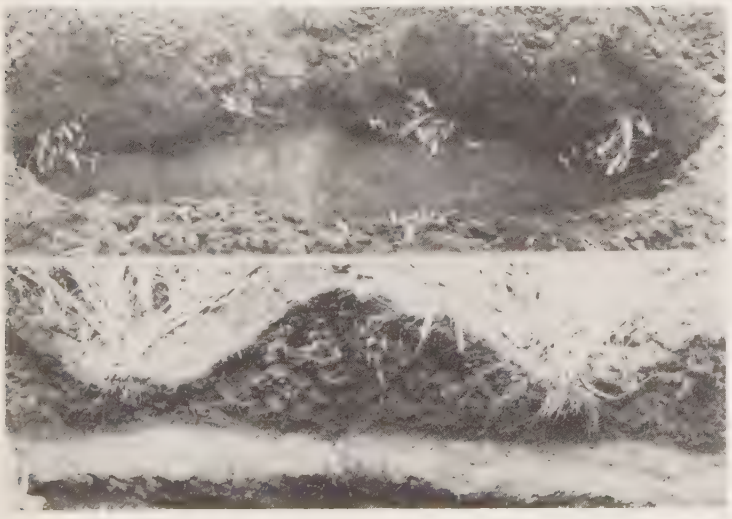


Figure 58. The upper section shows pockets of buried trash following moldboard plowing. The lower section shows a similar area 15 months later with only the slightest evidence of the trash pockets remaining.

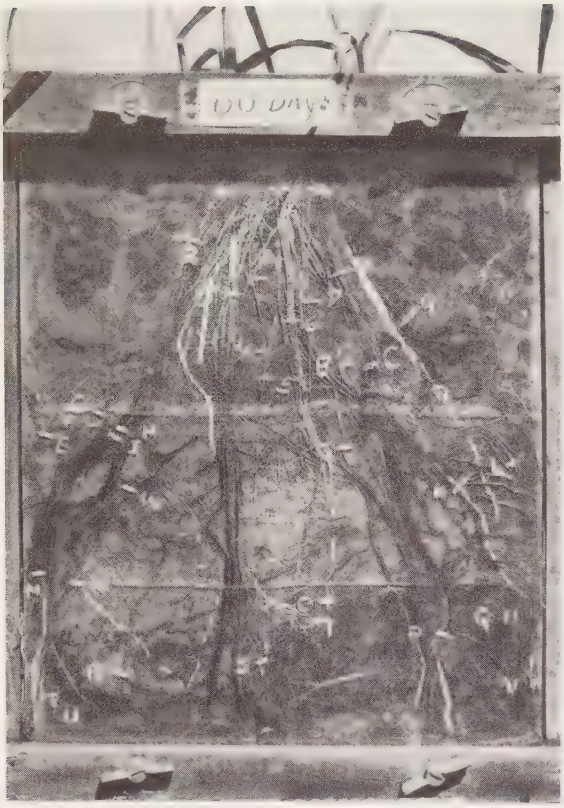


Figure 59. Root studies, using a window box technique, allow observation of daily growth rates and activities.

ing the first heavy fall rains. On the other hand, secondary tillage operations utilizing the disc harrow following prolonged winter rains or in the humic and hydrol humic latosols, often produce soil compacted severely enough to restrict root development.

SOIL COMPACTION RESTRICTS ROOT DEVELOPMENT

During the year, the study on soil denseness and cane root development was completed for the soils of the Wahiawa family and was started on the soils of the Kahana family. A window box technique was also utilized (Figure 59) which allowed daily measurements of root development and activity in soils in various states of denseness. A time-lapse movie was compiled showing the development of the seedpiece roots, the development of the shoot roots and the fact that they were diverted when they struck a layer of Wahiawa soil compacted to 90 pounds per cubic foot. After harvesting the crop, the root development ceased and a new root system developed from the ratoon shoots.

MOLDBOARD PLOW GIVEN EXTENSIVE FIELD TRIALS

During the past year, the experimental Teflon plow has been operated at Hilo Sugar, Paauhau Sugar Company, Ltd., Honokaa Sugar Company and Lihue. At each plantation there has been enough area plowed in enough different conditions to demonstrate some of the advantages and disadvantages of a moldboard plow with Teflon on the moldboards to give scouring. Plowing depth has ranged from 14 to 24 inches. Depth-of-plowing tests were installed at Hilo, Paauhau and Honokaa, to indicate the possible value of deeper plowing (Figure 60).

A great deal of the operation of this plow has been at depths which were greater than the standard depth for the respective areas. The shear device built into the standard of each plow bottom has been effective in protecting the plow structure from most of the effects of submerged obstacles.

One phase of the project work has pertained to improving the quality of the plow job by use of gauge wheeling. An objective is to arrive at gauge wheeling and adjustment of the plow suction, which, combined, will keep the plow rolling at a uniform set depth with no vertical support from the tractor. This work has progressed on an experimental basis to full gauging of the tool bar to which the plow is attached, and of one gauge wheel near the rear of the plow.

A faster plowing speed is required to give a smooth plow job with the present shape of moldboards. The optimum speed for the existing moldboards is to be determined. Part of the project work planned is a moldboard shape which will give a smoother job of plowing at the low speeds. The combined problems of the power required to shear and turn Hawaiian soil, the depth of plowing desired, and side draft, make it difficult to attain a combination of plow and prime mover which will give results approaching the ideal. Conclusions are being reached in this area which affect design directly.

Conclusions as to the economics of the use of Teflon to give scouring on a moldboard plow have not been conclusively reached. One phase is the type and thickness of Teflon used and the attachment of the Teflon to the moldboard. At the present time, intensive work is in progress testing different methods of attachment, from cementing to different sizes and shapes of strips, and replaceable sections. Some conclusions on the attachment of the Teflon are basic to a determination of the economics. It is expected that

Figure 60. Moldboard plow in operation at Lihue Plantation Company.

most of the final conclusions on this project can be reported within the next year (Figure 61).

Oahu Sugar fabricated a moldboard plow based on the initial results with the experimental plow. This plow has plowed approximately 500 acres during the past year. The results possible are very encouraging. Structurally, the plow has not been equal to the power of a TD-24 tractor. The mortality of the Teflon has been a continuing problem. Progress is being made and final conclusions can be made later.

Production has not been established on a quotable basis, but has generally ranged from one to two acres per hour. The type and location of the soil has been the greatest factor in production.

DRAFT AND STRESS TESTING

A portable two-channel Offner continuous recording strain gauge unit has been in use as a means of measuring the draft of a direct-mounted implement. Two box beam sections with strain gauges attached which can be inserted in the side arms of the tool frame assembly have been fabricated. The type P Dynagraph recording assembly has been calibrated to read the pull in pounds.

Also, a draft link with strain gauges attached has been calibrated as a means of recording the draft of a pull-type plow. Both applications of this equipment have been checked with a range of known loads and the maximum error can be held within plus or minus two and one-half per cent.

This will provide a means of accurately comparing the draft of different types of plows and determining the effect on draft of changes made to a specific plow. The initiation of this work has been delayed by operational problems and the necessity of first solving such problems on the moldboard plow as maintaining a uniform plowing depth.

Figure 61. Showing different patterns and techniques for attaching Teflon to moldboards. Teflon is cemented to rear bottom.

VARIETIES

FIELD YIELDS—A LOOK INTO THE PAST AND THE FUTURE

The impact of strikes, hurricanes, drought, and other factors affecting yields or profits in particular years, tend to obscure long-range trends in the industry. We are sometimes guilty of remembering that a particular field record was set with H 109, or with 100 pounds N, and not remembering more realistic and reliable long-term averages.

Since 1934, the HSPA has been compiling industry-wide annual production figures for the United States Department of Agriculture. While there are certain minor inaccuracies in individual figures, the averages and trends are quite significant.

Paraphrasing a comment quite frequently heard, "These new varieties are vigorous enough, but why has our juice quality gone down?" A look at the production statistics reveals that the average TC/TS ratio for the past five years (1954 to 1958), including 1958 with its extremely poor juices as a result of the strike, was 9.00. The 1953 to 1957 five-year average was 8.66 TC/TS. The 1934 to 1938 average was 9.12. For the same five-year periods, TSA improved from 7.28 during 1934 to 1938 to 10.06 in 1954 to 1958 (again including the poor 1958 yields resulting from the strike). The 1954 to 1957 average was 10.30 TSA.

The year 1953 was a remarkable year. In 1953, 23 of 28 plantations set new TSA records. Of the 23 which set new records, all but four have set one or more still higher records since. Four out of the five which did not set a record in 1953 have set new records since.

Also in 1953, 10 plantations set new records for good juice quality. At eight more plantations, the 1953 juice quality figure was second or third best since 1934. Only four plantations have set a new juice quality record since 1953. In general, irrigated plantations have shown more improvement in juice quality in recent years than have unirrigated plantations.

Risking the inherent dangers of broad generalizations, we might answer the obvious question, "What does this all mean?"

1. Over the past 20 to 25 years, yields of sugar per acre have been materially increased in all areas. This has happened in spite of mechanization with its accompanying problems of soil compaction and increased losses of sugar in the harvesting and milling processes.

2. Over the past 20 to 25 years, there has been net improvement of juice quality in many areas, and no marked lowering of juice quality in any area.

The next obvious question is "Why?" Certainly any improvement must be attributed to an interaction of a number of factors. The most important seem to be:

(a) New varieties
(b) Higher fertilization rates
(c) Improved weed control
(d) More sensitive measures of the needs of the plant for nutrients and water, and development of means to supply these needs.

What then of the future? The geneticists feel confident that there is still ample room for improvement. New and promising breeding materials are becoming available. There is room for improvement in fertilization practices, particularly in the matter of amounts and timing for optimum juice quality. Fertilization practices must be re-evaluated on new varieties. Herbicide practices must continually be subjected to economic study, both from the effect on weeds and the effect on cane. Improvements in irrigation, plowing and other cultural practices have promise of increasing profit per acre.

Any possible improvements must be carefully evaluated in field experiments to determine their real value. Herein lies a serious bottleneck to future progress. If hope is held that field yields can be greatly improved, or even maintained, a concerted effort toward increasing efficiency and reliability of field experiments is urgently needed. Trained task forces are a major step in the right direction but do not automatically solve all the problems of field experimentation. More reliable and efficient means of weighing cane and of analyzing it for juice quality are also needed. Studies of optimum plot size and plot layout are needed and high quality supervision of all phases of field experimentation. Given these things, together

Table 17. Number of Crosses Undertaken During 1958-1959 Crossing Season

General melting pot crosses	1,954
Leeward melting pot crosses	357
Windward makai melting pot crosses	331
Windward mauka melting pot crosses	162
Q.R. melting pot crosses	459
Bi-parental crosses	953*
Field crosses	170
1958-1959 total	4,386
1957-1958 total	4,442

* Includes 23 crosses for Dr. Price (cytological studies); 27 crosses for Dr. Stokes (USDA).

with the talent available in the Experiment Station, the agencies and on the plantations, future progress in sugar production seems assured.

THE 1958-1959 CROSSING SEASON

The crossing season began on November 14, 1958, and ended on January 13, 1959. Heavy tasseling and excellent weather during most of the crossing campaign resulted in a most successful season. While the total number of crosses made was slightly less than the previous year, the quantity of fuzz per cross was greater. The number of bi-parental crosses was the highest ever accomplished, reflecting good weather and increased emphasis on breeding with the most elite parents (Table 17).

PRELIMINARY SEEDLING TESTING

The regional station network continued to operate at capacity during 1959. In addition, there was increased interest on the part of some plantations in testing larger populations of seedlings in certain problem areas not adequately represented by any of the regional stations. Several thousand seedlings are usually distributed as "numbered 5x4's" to such areas.

The proposals to improve the efficiency in handling the increased number of seedlings entering 24-month testing, as discussed in last year's report, have been implemented on Kauai and Oahu and further expanded at HC&S. These proposals involved "30x24" plantings on plantation land loaned to the Experiment Station to receive selections from regional station 5x14 plots, instead of planting 20x20 plots on the regional stations. The net effect of this change is to

Table 18. 1959 Preliminary Testing Plantings*

	No. of Flats (No. of Sdlgs. per Flat—100-1000)	Unnumbered 5x3 and 5x4—No. of Sdlg. Plots	Numbered 5x4 No. of Sdlg. Plots	5x10 5x14 No. of Sdlg. Plots	10x20 No. of Sdlg. Plots	30x24 No. of Sdlg. Plots	40x40 No. of Sdlg. Plots
Regional stations							
Kailua Field Laboratory	2,215	3,084	381	.....	.....	.....	.....
Waipio Substation	1,394	17,374	9,679	2,570	.....	254[a]	.....
Helemano Variety Station	.....	2,440	2,603	581	.....	177[b]	.....
Hilo Makai Variety Station	232	3,630	2,483	451	69	.....	18
Hilo Mauka Variety Station	176	3,392	1,519	361	64	.....	16
Hamakua Makai Variety Station	1,134	3,204	2,574	451	62	.....	20
Hamakua Mauka Variety Station	217	7,426	2,406	364	49	.....	24
Kohala Variety Station	.....	1,937	1,048	282	57	.....	16
Kau Variety Station	351	1,234	1,907	577	84	.....	21
Lihue Variety Station	330	5,786	1,515	628	.....	48[c]	.....
McBryde Variety Station	728	6,540	4,692	837	.....	175[d]	.....
Plantations							
H. C. & S. Co.	.....	.....	6,787	1,409	.....	98[e]	.....
Kohala Sugar Co.	.....	2,377	5,309	364	.....	.....	.....
Paauhau Sugar Plantation Co.	.....	.....	.....	17	.....	.....	.....
Laupahoehoe Sugar Co.	.....	.....	500	.....	.....	.....	.....
Hutchinson Sugar Co.	.....	1,107	1,786	108	.....	.....	.....
Lihue Plantation Co.	.....	.....	1,885	123	.....	.....	.....
Kekaha Sugar Co.	.....	.....	.....	133	.....	.....	.....
1959 total	6,777	59,531	47,074	9,256	385	752	115
1958 total	6,821	62,287	23,667	10,734	554	452[f]	109

* Breeding and Spreading canes at Kailua Field Laboratory are not included in table. Plantation 10x20 and 40x40 plantings tabulated in Table 19.

Notes:
[a] Planted at Ewa, Kahuku, Oahu Sugar, Waialua and H.C.&S.
[b] Also planted at Waialua and H.C.&S.
[c] Planted at Lihue Plantation Co.
[d] Also planted at Kekaha and Olokele.
[e] In addition to 57 plots sent from Waipio and Helemano.
[f] 20x20 plots.

Table 19. Number of Preliminary Tests Installed by Plantations—1958-1959
(Fiscal Year Ending June 30, 1959)

	Kauai	Oahu	Maui	Hawaii	Fiscal 1959 Total	Fiscal 1958 Total
10x20 and 10x25	28	18	9	57	112	51
30x30, 40x40 & 50x50	27	21	9	29	86	33

make the fourth stage of selection at two years, instead of having the fifth or 40x40 stage as the first two-year selection stage. The improved procedure will make it possible to see many more seedlings at 24 months and will thus eliminate non-carry-over types before the more expensive 40x40 stage of testing. The six-line 30x24 plot has proved to be more efficient and reliable than the four-line 20x20 plot for this purpose.

Table 18 tabulates the plantings in the preliminary testing program by regional stations and cooperating plantations.

VARIETY TESTING BY THE PLANTATIONS

The intensity of plantation variety testing, as shown in Table 19, reflects two factors which reduce the comparability of this year's data with that of previous years.

The effect of the 1958 strike caused, first, an abnormal reduction in tests installed in that year, as shown in Table 19. Secondly, the 1959 figures are inflated by a desire to catch up after the strike was over.

A more realistic indication of trends can be had by comparing the average of 1958 and 1959 fiscal years with 1957 as the last normal year. This is shown in the following compilation.

	Fiscal 1958 & 1959 (Avg.)	1957
10x20 & 10x25	82	73
30x30, 40x40, 50x50	60	79

These figures show an encouraging increase in the number of 10x20 and 10x25 tests installed, but an alarming decrease in the number of preliminary yield trials installed. Some of the decrease can be attributed to inability to plant 10x20's or to cut seed in existing 10x20's during the strike period.

REPLICATED TESTS INSTALLED DURING 1959 FISCAL YEAR

Table 20 shows the number of entries in replicated tests. While the fiscal 1959 period shows an encouraging gain over the last normal year, 1957, it is not entirely a genuine gain. In the 1956-1957 period, replicated tests were usually five to eight replications. Today, most replicated tests are in the form of replicated checks in an augmented block 40x40 or 50x50 design, and have three or four replications. Thus, considering the need to get sound information on which to base management decisions, the Genetics Department feels that the plantation variety testing program needs more emphasis.

DISTRIBUTION OF SEED

In addition to their preliminary testing functions, the regional variety stations serve as seed propagating and distributing centers. Seedlings which show promise in preliminary tests at the regional stations are

Table 20. Replicated Variety Tests Installed by Plantations
(July 1, 1958 to June 30, 1959)

Variety	Kauai	Oahu	Maui	Hawaii	No. of Entries Total
37-1933	8	7	5	1	21
38-2915	....	4	3	....	7
4443	....	....	....	1	1
39-5803	1	4	1	....	6
7028	6	....	....	1	7
41-1045	....	....	....	1	1
3340	....	....	....	7	7
44-2772	....	....	....	7	7
3098	....	....	....	14	14
45-2120	1	....	....	....	1
2708	1	....	....	....	1
2860	4	1	....	....	5
46-945	....	1	....	....	1
3037	1	....	....	....	1
48-3845	....	1	....	....	1
4046	....	1	....	....	1
4178	1	1	....	....	2
4605	8	....	....	....	8
4611	....	2	....	....	2
4646	5	....	....	....	5
4899	3	....	....	....	3
49-5	18	13	5	38	74
104	6	4	....	....	10
612	....	....	....	1	1
3533	14	9	3	1	27
50-723	....	....	....	1	1
2542	....	1	....	5	6
6062	....	1	....	....	1
6822	....	....	....	2	2
6877	1	3	....	....	4
7209	14	15	7	3	39
51-760	....	....	....	2	2
2530	1	....	....	....	1
4336	1	....	....	....	1
8194	....	7	1	2	10
52-123	....	....	....	15	15
8176	....	1	....	....	1
Totals for:					
1958-1959	94	76	25	112	297
1957-1958	69	19	18	28	134
1956-1957	63	52	38	75	228

Table 21. Seed Shipments to Plantations
(July 1, 1958 to June 30, 1959)

Source	For Seed Nurseries (tons)	For 10x20 No. of Plots	For 40x40 No. of Plots
Kailua Field Laboratory	1.83	.....	.....
Waipio Substation	6.35	1,962	11
Helemano Var. Sta.	.38	132	4
Hilo Makai Var. Sta.	3.16	1,513	.....
Hilo Mauka Var. Sta.	.23	544	.....
Hamakua Makai Var. Sta.	4.68	950	11
Hamakua Mauka Var. Sta.	.....	184	.....
Kohala Var. Sta.	3.03	20	1
Kau Var. Sta.	.25	10	18
Lihue Var. Sta.	.....	106	8
McBryde Var. Sta.	4.22	206	8
Totals	24.13	5,627	61
Total 1957-1958	18.69	2,691	35

spread in seed nurseries for distribution to the plantations for further testing. Details of seed distribution are shown in Table 21.

CYTOLOGICAL INVESTIGATIONS

In the cooperative USDA-HSPA investigations of sugar-cane cytology, emphasis has been placed on determining chromosome numbers of the wild canes collected during the 1957 expedition to New Guinea. Very high chromosome numbers are being found in many of these canes. One seedling has been found with approximately 195 to 205 chromosomes.

During the 1958-1959 tasseling season, Dr. Sam Price collected pollen-mother-cell material from some of the New Guinea canes that have already been established in the world collection at the United States Sugar Crops Field Station, Canal Point, Florida.

FLOWERING OF SUGAR CANE

Cooperative work on flowering with Dr. Graham Davis, USDA, continued along four general lines: inhibition of flowering in the field, mechanism of inhibition, induction of flowering out of season, induction of flowering in reluctant varieties.

Timing of Treatment for Inhibition

Last year it was reported that very late treatment with CMU resulted in the best control of flowering. It was recommended that spraying be delayed until the second week in September and could be continued until the 12th or 13th. This was checked again at the Makiki Station on young 37-1933. The studies were made with stalks selected for uniform sizes and tagged on August 20.

The effects of CMU were compared with maleic hydrazide (MH) and with trimming of spindles on a single date or on three successive weeks.

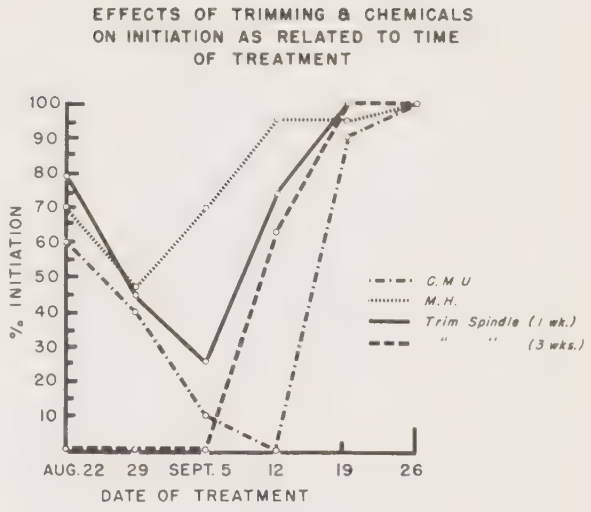


Figure 62.

The results shown in Figure 62 confirm and extend the earlier conclusions as follows:

(a) MH is not as effective as CMU at the levels used.

(b) To have maximum effect, MH must be applied earlier than CMU.

(c) CMU acts very quickly on the initiating mechanism. It has maximum effect as late as September 12 and practically none by September 19.

(d) Cutting out the spindle on September 5 almost eliminates initiation; trimming it for three successive weeks before September 5 completely stops it.

Effect of Rain on CMU Sprays

With the cooperation of the Hilo Substation, a number of strip tests were done in Hawaii. These were the first flower control studies using CMU on the Big Island. Unfortunately, most of the fields selected did not flower heavily enough to make the test a satisfactory one. However, aerial photographs showed some strips of good control.

Meanwhile, detailed tassel counts of plots within the sprayed strips have been furnished by members of the agriculture departments of the following plantations: Laupahoehoe Sugar Company, Hamakua Mill Company, Honokaa, Hilo Sugar, Onomea Sugar Company, and Paauhau. The details, which are of great interest, are summarized here. The effects of five pounds of CMU per acre varied immensely. In some cases, no

Figure 63. First tassel to emerge after application of an artificially imposed day length of 12½ hours in April.

Figure 64. Narenga tassels and flags produced on eight-hour day length.

Table 22. Effect of Rain on CMU Spray to Control Tasseling

Treatment and No. of Replications	Percent No. Tassel Stalks
3 check plots (no CMU)	0
5# CMU/acre on 9/9/58	
1	100
2	92
5# CMU/acre on 9/9/58 followed by ¼" "rain"	
9 hours after spray	100
30 hours after spray	100
54 hours after spray	100
78 hours after spray	96
5# CMU/acre on 9/9/58 followed by ½" "rain"	
9 hours after spray	100
30 hours after spray	100
54 hours after spray	100
78 hours after spray	100
5# CMU/acre on 9/9/58 followed by 1" "rain"	
9 hours after spray	100
30 hours after spray	84
54 hours after spray	100
78 hours after spray	100

control whatsoever was obtained. In others, the control was complete. This did not depend on variety. For the first time, CMU has been tested on a number of varieties. It has been found to be very effective in some instances on 44-3098, 38-2915, 44-2772, 49-134, 49-5 and 49-104.

Since the frequent rains in some areas of Hawaii might render CMU treatments ineffective, a comprehensive "rain" test was installed at the Makiki Station.

The results in Table 22 show that the effectiveness of the five pounds of CMU per acre was not reduced by one inch of rain in the evening nine hours after a morning application. Note that five pounds of CMU per acre gives almost total control of flowering in 37-1933 which flowered 100 per cent in the three check plots.

One new chemical formulation was tested for flower control. DuPont's Neburon-Butyl Compound of DCMU, applied by hand spray at eight pounds per acre on September 9, gave good control of tasseling of variety 37-1933.

Induction of Flowering by Controlled Photoperiod

A large number of plants of variety 37-1933 have now been induced to flower in early summer and crosses have been made with early flowering varieties.

The general procedure was to marcotte in the winter plants which were too young to initiate the previous September. After the marcotted plants had well-established root systems, they were subjected to 38 days of pretreatments which differed only in the amount of light received. On April 14, they were divided into four groups, all of which received eight hours of Makiki daylight (8:00 a.m. to 4:00 p.m.). The remaining 16 hours were spent in the dark room with an additional four and one-half hours of light of the following kinds:

Group 1. 1 fc of mixed light

Group 2. 3 to 364 fc of incandescent light

Group 3. 340 to 600 fc of fluorescent light

Group 4. 300 to 480 fc of incandescent plus fluorescent light.

The day length for all groups was, therefore, 12½ hours, differing only in the nature of the four and one-half hours of supplemental light.

Table 23. Early Summer Flowering of Variety 37-1933 Following Induction in 12½ Hour Photoperiod in Controlled Light Chambers

Group	Initiation %	Average Days to Visible Emergence*
1	45.4	90
2	100.0	159
3	90.9	127
4	90.9	131

* Time when tip of tassel is first visible.

Table 23 summarizes the results from all three pretreatments.

Most of the flowers emerged, and were used by the Genetics Department for crosses never before made in Hawaii. These produced approximately 300 37-1933 x Narenga seedlings, and possibly others from Eulalia, 51-NA-106 and Isiolo.

Figure 63 shows the first tassel emerging from marcotted 37-1933 plants, and Figure 64 shows Narenga tassels and flags produced on an eight-hour day.

WEED CONTROL

COORDINATED INTERDEPARTMENTAL PROJECT ON WEED CONTROL INITIATED

This last year a cooperative interdepartmental project on weed control was organized which places the major functions and studies under three different departments and in cooperation with the Island Representatives, as follows:

Department	Major Function or Study
Chemistry	1. Study of basic herbicides preparatory to formulating. 2. Development of formulations. 3. Mixing plant problems. 4. Analyses of soils and sugar cane relative to safe use of the herbicides.
Agronomy	1. Field testing of herbicides. 2. Studies on safe usage of the chemicals. 3. Study of application equipment, calibration and spray patterns. 4. Close consultation with plantations on their weed control practices as related to other methods employed in culture of sugar cane.
Field Engineering	1. Development and fabrication of herbicide application equipment. 2. Evaluation of materials for fabrication. 3. Study of protective coatings for application units.

NEW CHEMICAL HERBICIDES SCREENED

Pentachlorobenzenethiol (PCBT)

This chemical, a duPont development product, is the sulfur analog of pentachlorophenol (OSA) and might be expected to show similar contact herbicidal properties. It may also possess fungicidal activity. The gray-white 95 per cent active powder has a faint musty odor and does not cause sneezing.

Solubility of PCBT in aromatic weed oils or in methanol was negligible, cold or when heated; the sodium salt prepared by reaction with sodium hydroxide (three parts NaOH to 20 parts by weight of PCBT) was sparingly soluble in hot water. Application will be possible only as dilute water solutions of the sodium salt, or as a suspended powder.

Pentabromophenol (PBP)

A product of the Michigan Chemical Corporation, this purple colored, flaked material has fungicidal activity. Herbicide properties are unexplored. The sodium salt is very sparingly water soluble.

Inverton 245

Inverton 245 is a proprietary concentrate liquid containing 22½ per cent of 2,4,5-trichlorophenoxyacetic acid and an emulsifier capable of forming water in oil (W/O) or "inverted" emulsions, when the concentrate is diluted first with light fuel oil and then with water to a final dilution of 0.03 pound of 2,4,5-T equivalent per gallon. The resulting emulsion was extremely thick, about the consistency of cold cream, and would require special mixing and application equipment.

Garlon

This proprietary emulsifiable liquid contains the diethylene glycol ester of dalapon (four pounds) and the polypropylene glycol butyl ether ester of silvex (one-half pound per gallon). The hormonal spray has been suggested for industrial areas to control both hard grasses and broadleaves.

Garlon cannot be shipped in unlined metal containers as the dalapon constituent hydrolyzes slowly to form a corrosive liquid. The emulsion with water deteriorates with time, due again to the dalapon hydrolysis.

Urox and Urab

CMU (monuron) and PMU (fenuron) form complex salts when combined in a one-to-one molar ratio with trichloroacetic acid. The salts are formulated as granular pellets of 11 and 22 per cent active agent, and as three pounds active per gallon liquids for oil dilution. The manufacturer recommends these products for brush control. Small amounts of water release enough of the trichloroacetic acid which is corrosive to metals. The oil-soluble form cannot be formed into an emulsion but must be used only in oil dilution.

Hexachloroacetone (HCA)

This is a liquid available at 20 or 75 per cent active concentration, recommended by the manufacturer for systemic control of grasses and nut grass. Emulsions

cannot be made with this material; oil solutions, using aromatic oils, or diesel, have limited stability, and insoluble tars are formed within a few minutes after mixing. In the presence of moisture, hexachloroacetone hydrolyzes slowly to trichloroacetic acid and chloroform. The solutions and original packaged materials absorb enough atmospheric moisture to become highly corrosive to metal containers. Stability of the product, even in glass containers, has been very poor at Hawaiian temperature and humidity levels.

Fluorine Analogs of 2,4-Dichlorophenoxyacetic Acid

A new, rather extensive group of herbicidal materials has appeared, in which one or more positions of the benzene ring of the phenoxy acid is substituted with a fluorine atom. Chlorine is also present in most of the chemicals. Based in general on 2-fluoro, 4-chlorophenoxyacetic acid or its analogs, the materials are available in development quantities as free acid (liquid) concentrates, water-soluble amine salts and oil-soluble emulsifiable esters. Investigation of this important group of chemicals will take some time. Some of them are known to inhibit seed germination.

ACP 616

A granular, hygroscopic, physical mixture of equal parts by weight of 3-aminotriazole and ammonium thiocyanate, this product is water-soluble to form a two pound per gallon concentrate (pH 6.0). E50 stock solution cannot be used as a wetting agent except in very dilute solutions, and ARCADE Concentrate did not emulsify at 0.1 pound per gallon in the aqueous phase.

ACP 617

This physical mixture of 3-aminotriazole and sodium pentachlorophenate (WSA) is a light tan powder causing respiratory discomfort and sneezing when handled. A two pound per gallon concentrate could be prepared having a pH over 11.0. E50 stock solution was compatible as a wetting agent.

Dalapon Ester

An emulsifiable diethylene glycol ester of dalapon, having six pounds per gallon active dalapon equivalent, was obtained. Aqueous emulsions of the ester hydrolyze relatively rapidly just as sodium dalapon solution does; the hydrolyzed solutions are corrosive to metals. Preliminary tests indicate the oil-soluble form of dalapon is more rapidly absorbed by hard grasses than is the water-soluble form, and may have application on resistant strains. Cane damage can be expected to be more severe than is the case with sodium dalapon where the emulsions come in contact with the cane plant. The ester can be mixed with 2,4-D esters and emulsified.

Pre-emergence Chemicals

a. M-1329. The first, as yet unnamed, member of herbicidal phosphorous organic chemicals, relatives of malathion, has appeared as a two pound active per gallon emulsifiable concentrate. The 0-2, 4-dichlorophenyl-O-methyl isopropylphosphoramidothioate is recommended by Dow for pre-emergence grass control. The odor is rather unpleasant, somewhat like malathion's.

b. DAC-893. A 50 per cent wettable powder formulation, DAC-893 represents still another completely new chemical type and marks the entrance of Diamond Alkali into the pre-emergence field. The active agent is the most water-insoluble pre-emergence chemical yet known: 0.5 ppm or less. It is to be applied as an aqueous suspension.

c. duPont 685. The chemical: 1-chloro,N'-(3,4-dichlorophenyl)-N, N-dimethylformamidine is a highly reactive liquid (8 pounds active per gallon) with contact and pre-emergence properties. The 1-chloro atom is easily replaced by reaction with water, alcohols, amines and phenols to form a substituted urea (in the case of water) and hydrochloric acid. Plant and soil moisture, as well as any water in tanks, spray equipment, atmosphere, etc., reacts to form DCMU (diuron) and hydrochloric acid.

Practical application of duPont 685 to our present weed control practice will be most difficult. Emulsions are not possible; oil solutions with available oils are costly, and *all* oils which would be practical to use react with the 685 to some extent. Kerosene and mineral oils available here have small amounts of water precipitating crystalline DCMU; aromatic oils form insoluble tarry resins with it. Diesel oils, if free of "detergent" or other additives, are the most satisfactory diluents. Even local "additive free" diesel oils, however, react with the 685: initially a fine flocculent substance is formed in small quantity which can be settled in an hour or so and discarded. The clear supernatant oil should be applied within 24 hours; tarry precipitates continue to form on prolonged storage.

Storage of the technical grade 685 for long periods must be avoided as atmospheric moisture at our ambient temperatures reacts with it to precipitate crys-

Table 24. Promising Triazines Under Study

Name	Water Solubility (ppm)	Substituent on Position 2	4	6
simazine	5	chloro	ethylamino	ethylamino
propazine	8.6	chloro	isopropylamino	isopropylamino
trietazine	20	chloro	diethylamino	ethylamino
ipazine	40	chloro	diethylamino	isopropylamino
atrazine	70	chloro	ethylamino	isopropylamino
G30026	260	chloro	methylamino	isopropylamino
G30451	42	chloro	propylamino	isopropylamino
simetone	3200	methoxy	ethylamino	ethylamino
prometone	750	methoxy	isopropylamino	isopropylamino
atratone	1800	methoxy	ethylamino	isopropylamino
G32292	3500	methoxy	methylamino	isopropylamino
G31717	.....	methoxy	diethylamino	isopropylamino

talline DCMU which forms in hard clumps nearly impossible to dissolve with solvents. Any solutions of 685 which have reacted with or absorbed moisture are corrosive due to the acid formation.

d. Triazines, simazine and related materials. Many derivatives of 1,3,5-triazine substituted at the 2, 4 and 6 positions have herbicidal activity. Two of these, simazine and ipazine (formerly G30031 or "oil-soluble simazine"), have been tested here. Extensive preliminary study of other compounds has started. Promising new triazines, of which we have small quantities, are listed in Table 24.

NEW PROCESS FOR AQUEOUS EMULSIONS OF PENTACHLOROPHENOL IN OIL

A cold processing method of dissolving the OSA in aromatic oils, using a minimum amount of anhydrous methanol, has been worked out during the year and is currently in plantation use. The methanol, two per cent of the total volume, is placed on the OSA in a tank or drum and a "Lightnin" mixer is all that is required to bring the treated OSA into solution in the oil. This OSA in oil concentrate, which may contain up to 1.5 pounds of OSA per gallon, is completely stable in open containers and may be used for: 1) ARCADE concentrate in the usual way; 2) INVER-ARCADE, the inverted emulsion which is oil dilutable, adheres to vegetation and will not wash off in the rain, and 3) OSA Emcon, an emulsifiable concentrate which may be diluted directly with water or with water containing 0.1 per cent active wetting agent. The emulsifiable concentrate has been modified slightly from the first formulation so that it is emulsifiable with water without requiring an additional wetting agent in the dilution of water.

Perconcentrates, or higher concentrates of OSA, can be made, containing up to eight pounds of OSA per gallon. The OSA perconcentrates can be used as a source of soluble OSA for oil addition or as a fine dispersion of OSA in irrigation water.

THICKENING AROMATIC OILS TO REDUCE DRIFT

Wherever there is a practice or a future possibility of applying straight oil sprays, interest has been shown in developing thickening agents to reduce wind drift and to provide a suspending agent for wettable powders dispersed in oil.

One to two per cent by weight of a technical grade aluminum stearate (aluminum distearate) may be dissolved to a clear solution in oils (diesel, aromatic, mineral) at a temperature of 115° C. or above. The oil thickens slightly when cool. A range from thin oil to grease consistency is possible. At 1.5 per cent in aromatic oil, DCMU may be permanently suspended.

EMULSION OF METHYL BROMIDE IN OIL

Methyl bromide is an excellent soil sterilant and seed control agent, but since it is a gas at normal temperatures and pressures, either a plastic cover is required or the gas must be injected at considerable depth into the soil. Most of the chemical is lost without absorption into seeds and plants. Methyl bromide is soluble in weed oils, diesel and aromatic, up to two pounds per gallon, to form an oil solution stable at normal temperatures and pressures. An emulsion similar to ARCADE Concentrate was made using Tergitol NPX as the emulsifier at an oil to aqueous ratio of two to one. This emulsion can be diluted with water as desired, or it can be dripped into an irrigation system carrying seed from outside the cane fields. Methyl bromide is toxic to human beings, and preliminary testing, even of the oil solution emulsions, must be carefully supervised.

NEW WETTING AGENTS, EMULSIFIERS AND STABILIZERS APPEAR

A large number of new surfactants, principally oil-soluble, were investigated during the year and a number of materials at hand were re-examined specifically for the inverted, water-dispersed-in-oil (W/O) emulsions and for the emulsifiable concentrate of pentachlorophenol. One new water-soluble emulsifier, chemically similar to E50 and Ultrawet K, has appeared on the local market.

EMULSIFIERS FOR INVERTED W/O EMULSIONS

Approximately 20 to 25 new emulsifiers were investigated for preparation of a stable inverted emulsion of pentachlorophenol dissolved in aromatic oil. An inverted emulsion of a medium viscosity capable of application with regular plantation spray equipment was prepared using Petronate CR (L. Sonneborn and Sons, Inc.). Very thick emulsions similar to Inverton 245 were prepared using Span 80 (Atlas Powder Co.). However, present plantation mixing facilities could not turn out such a thick emulsion, nor could it be applied without special equipment. The water-to-oil ratio in all the inverted emulsions where aromatic or diesel oils were used was best at two to one.

Development of the emulsifiable concentrate of OSA in oil depended on finding an emulsifier which would not react with pentachlorophenol and which would be oil-soluble but not require a water-soluble wetting agent for the dilution water. Many anhydrous anionic emulsifiers will form excellent emulsions if the wetting agent is also added to the water. One anionic system has been found which performs the emulsification in plain water, provided the water is not excessively hard. This information will be released as soon as it has been thoroughly tested by the Island Representatives.

Kreelon 8G (Wyandotte Chemical Co.)

Kreelon 8G is a dry, powdered sodium alkyl aryl sulfonate recently introduced locally. It is 85 per cent active and will easily form a one pound per gallon stock solution in cold water. As an emulsifier for ARCADE Concentrate, it is equal to E50 and superior to Ultrawet K at the same level of active agent. The one pound per gallon stock solution is corrosive to metals just as the other similar products are.

Arctic Syntex 036 (Colgate)

Arctic Syntex 036 is available locally as a 100 per cent active liquid, nonionic wetting and dispersing agent. It is similar in properties to Triton X-100 and Tergitol NPX as an emulsifier for 2,4-D esters at five per cent by volume. It cannot be used in ARCADE formulations as it, like other nonionics of its type, reacts with OSA.

Plyac (General Chemicals)

Plyac is an emulsion of an oxidized polyethylene intended as a sticking agent when applied to vegetation at the rate of two to four ounces in 100 gallons of spray solution.

CORROSION INHIBITION AGENTS PLACED IN OILS

Oil-soluble surfactants of the type which form inverted emulsions often show corrosion inhibition properties when dissolved in an oil and applied to metal. They act by emulsifying and removing from the corroding site a thin adherent layer of water and its dissolved salts. The surfactant removes this corrosive film and aids in the "wetting" of the metal surface by the oil.

After testing numerous compounds, the Petronate CR invert emulsifier was found to be quite effective at one to two per cent levels in a base oil (motor oil, diesel, mineral oil, etc.). Efficiency of the corrosion-resistant agent appears to parallel its effectiveness as an emulsifier for water in oil. Also, currently under test is an asphalt base paint coating containing two per cent Petronate CR, to prevent blister rusting under the paint film.

OIL RESISTANT ELASTOMER TUBING AND HOSE TESTED

"Viton," a duPont fluorine containing elastomer, has been tested against a number of chemicals and solutions in commercial or experimental use in the sugar industry. The tubing resembles neoprene but is more resistant to oils. It has outstanding resistance to heat, also, which makes it useful as a steam hose. As Table 25 shows, Viton cannot be used with aqua ammonia, and probably not with DD fumigant for prolonged periods.

ANALYTICAL METHODS DEVELOPED FOR ANALYSIS OF HERBICIDES

During the year, procedures were worked out for the analytical determination of dalapon in stored bulk quantities by hydrolysis and determination of total chloride; for the determination of 2,4-D acid equivalent in 2,4-D esters by adaptation of the American Oil Chemical Society method for fatty acid content of natural and synthetic oils; and for the determination of simazine residues in plants and soils.

Since the determination of simazine involves solvent extraction of unadsorbed simazine from a treated soil or plant (followed by acid hydrolysis and spectrophotometric determination of hydroxysimazine at 240 mu wave length), it can be argued that the analytical

Table 25. "Viton" Tubing Tested Against Chemicals in Use Commercially or Experimentally

Type of Liquid	Increase in Weight After: 1 week	2 weeks	1 month
	%	%	%
55AR oil (Standard)	0.266	0.383	.448
4276 oil (Union)	0.168	0.264	.304
Diesel oil	0.071	0.131	.131
Socal #2 (Standard)	2.038	3.006	4.448
E-50 solution	0.143	0.220	.228
ARCADE concentrate (undiluted)	0.296	0.400	.400
INVERARCADE	0.280	0.398	.481
Isooctyl 2,4-D ester	0.060	0.060	.079
2,4-D amine (Dow-40)	0.124	0.192	.192
DD fumigant (Shell)	7.880	10.109	10.399
12% OSA in aromatic oil	0.136	0.190	.277
Sodium TCA concentrate (4 lb./gal.)	0.226	0.402	.402
OSA perconcentrate (7 lb./gal.)	2.590	3.728	5.153
Aqua ammonia (reagent, 28%)	12.180	15.773	66.672
EDB fumigant	1.295	1.966	2.895
BBC fumigant	0.241	0.482	.652

data for soils represent "available simazine" active in weed control rather than total adsorbed and unadsorbed chemical. The latter is more nearly the case in analysis of residual CMU and DCMU in soils.

AGRONOMIC ASPECTS OF WEED CONTROL COVER MANY PHASES

The main activities of the agronomic weed control project during the past year have been the following:

1. Field screening of new herbicides.
2. Study of effects of herbicides on sugar cane.
3. Study of herbicide tolerant species and strains.
4. Time lapse movies.
5. Development of low pressure spraying for reduced drift.
6. Coordinated interdepartmental project on weed control.

Field Screening of New Herbicides:

Simazine (2-chloro-4,6-bis(ethylamino)-s-triazine). Tests have continued in order to compare simazine with CMU and DCMU at equal poundage per acre for pre-emergence control of general weed growth and for post-emergence control of manienie. Simazine at four pounds per acre has continued to show pre-emergence value about equal to that of DCMU and slightly longer than CMU. It has shown no post-emergence effect even at 100 pounds per acre, whereas from 50 to 75 pounds of CMU or DCMU have killed well established stands of manienie. Registration of simazine for use in sugar cane is expected soon.

Ipazine (G30031). (2-chloro-4-diethylamine-6-isopropyl-amino-s-triazine). This oil-soluble form of triazine at four pounds per acre has shown pre-emergence control equal to that of simazine. An additional advantage is that it can be applied either in oil or as an emulsion with water. As such, it can be used for contact post-emergence as well as for pre-emergence control.

TBA (2,3,6-trichlorobenzoic acid). This chemical has given the most promise for control of deeply-rooted rhizomatous species such as wing-leaved passion flower *Passiflora pulchella* and field bindweed *Convolvulus arvensis*. Levels of 10 to 20 pounds per acre are needed. At these levels, there has been considerable damage to sugar cane.

Amitrol (3-amino-1,2,4-triazole). Combinations of Amitrol with dalapon and with 2,4-D appear to have values for both pre-emergence and post-emergence weed control. Because the Amitrol causes rather severe chlorosis in sugar cane when it comes in contact with the plants, the chemical has not been used on large-scale infield tests. Thus far, it has not established any particular advantage over other herbicides presently in use.

Emid (Amide form of 2,4-dichlorophenoxyacetic acid),. This is a form of 2,4-D that must be applied as a wettable powder. It has shown no superiority to other forms of 2,4-D.

EPTC (Eptam) (Ethyl N-N-di-n-propylthiol-carbamate). At levels of 20 to 25 pounds per acre, this herbicide has given good results on nut grass as well as for pre-emergence control. Its availability is in doubt, since it was taken off the market by the manufacturer. Crop damage from EPTC can be expected at the above dosages.

MCPA (2-methyl-4-chlorophenoxyacetic acid). This herbicide has about equalled 2,4-D for pre-emergence and post-emergence weed control when applied at the same dosages.

Dalapon DEG ester (DEG ester of 2,2-dichloropropionic acid). Several tests have shown the ester form of dalapon to be as good as or better than equal dosages of sodium dalapon for control of manienie. Thus far, however, it has not proved successful in controlling the strains of manienie which are tolerant of sodium dalapon.

DuPont 685 (1-chloro-N'-(3,4-dichlorophenyl)-N, N-dimethylformamidine). Large scale testing of this herbicide is just beginning. It is difficult to handle since it is reactive with all aqueous materials and has been reactive as well with every form of oil in which

it has been applied. It is possible to apply it in one diesel oil, as specified with the test outlines. No screens in the spray equipment strainers should be smaller than 50 mesh. Water must be completely eliminated from the spray equipment before spraying the 685 formula.

Herbicide Formulations:

Dalapon emulsion (Dal E). This formulation has proved effective particularly on Hilo grass *Paspalum conjugatum*. The action is more rapid than that of dalapon in water.

Inverted dalapon emulsion (I Dal E). This formulation appears to have value for grass control under wet conditions, but requires further testing.

INVERARCADE and INVERCADE (IARC and ICADE). These two formulations are the counterpart of ARCADE and CADE except that they form water-in-oil emulsions instead of regular oil-in-water emulsions. The inverted (w/o) emulsions have shown some value for contact control of weeds under wet conditions.

INVERTON (Dow M-1123). This is a Dow Chemical Company formula containing 2,4,5-T in an inverted (w/o) emulsion. Its greatest value is for use under wet conditions.

EFFECTS OF HERBICIDES ON SUGAR CANE GIVEN CLOSE SCRUTINY

Tests were conducted with CMU, DCMU and simazine on 10 different soils to determine the effect of different levels of the herbicides on varieties 37-1933 and 49-5. Each of the above chemicals was mixed throughout six inches of soil in pots at the rate of 0, 3.5, 7.0, 14.0 and 28.0 pounds per one-half acre foot. This amounted to 0, 2.5, 5.0, 10.0 and 20.0 parts per million in air-dry soil. Sugar-cane seedpieces were planted in the treated soil.

Effects of CMU on the development of top growth of 37-1933, in relation to organic matter, pH and P_2O_5, are shown in Table 26.

Effects of CMU on cane grown in phosphorus deficient soil and in a soil with adequate phosphorus are compared in Figure 65. The difference in organic matter in these two soils as shown in Table 26 should also be noted. pH is about equal in the two soils.

Differential tolerance of the two varieties to CMU, DCMU, and simazine are shown in Figure 66.

FACTORS AFFECTING POSSIBLE HERBICIDE DAMAGE TO CANE PLANTS BY CMU, DCMU AND SIMAZINE

From the detailed studies on 10 different soils and analyses of soil and sugar cane from damaged areas, the following information can be summarized with regard to factors affecting cane growth.

Soils

Most of the damage to sugar cane from CMU or DCMU has been on the low humic latosols. Some damage has been noted on sandy soil. These soils have been the lowest in organic matter and in most, but not all, cases where damage has been found, the pH has been above 7.0. Recent studies have shown that damage from CMU has resulted where the particular soil was low in P_2O_5, as in Figure 65. All of these factors are considered important.

Damage from CMU has recently been observed on hydrol humic latosol when plowing was deep and where planting was done in subsoil. Prior to deep plowing, this was not the case.

Herbicide

All of the studies with CMU and DCMU have shown less damage to sugar cane from DCMU, as shown in Figure 66. For this reason, it has been

Table 26. Bio-assay of Effect of 5 ppm CMU in Sugar Cane Variety 37-1933 in 10 Different Plantation Soils 11 Weeks After Planting

Plantation	Field	Soil Family	Green Top Growth		Organic Matter	pH	P_2O_5
			Check	5.0 ppm			
			gms.	gms.	%		ppm
Kahuku	9	N-5 Kohala	60.8	7.4	1.23	6.7	3
Oahu Sugar	26	V-1 Kawaihapai	421.5	397.4	3.34	6.6	285
Kahuku	3	H-2 Kalihi	75.6	83.5	3.12	6.6	24
Kahuku	4	R-1 Haleakala	107.5	44.6	2.98	7.8	210
Kahuku	47	V-1 Kawaihapai	219.0	119.5	2.19	6.1	28
HC&S	608-1	N-1 Molokai	34.2	9.5	1.37	7.8	58
HC&S	608-2	N-1 Molokai	93.4	17.0	2.20	7.1	19
HC&S	816-1	N-1 Molokai	143.5	9.0	2.16	7.6	78
HC&S	816-2	N-1 Molokai	192.3	10.4	1.49	7.1	145
HC&S	104	N-1 Molokai to T-3 to Haiku	350.2	439.8	3.29	6.2	47

Figure 65. Effect of adding phosphorus to the soil as related to CMU symptoms and damage to 37-1933.

ppm CMU	Check	2.5	5.0	10.0	20.0
lbs/A CMU/6"	0	3.5	7.0	14.0	28.0

a. Field 9 soil from Kahuku analyzed 3 ppm P_2O_5 with no addition of phosphorus. Organic matter was 1.23%. Note severe damage from CMU.
b. Field 9 soil from Kahuku with 200 pounds per acre P_2O_5 added. Damage from CMU was greatly reduced as compared to a.

c. Field 26 soil from Oahu Sugar Company analyzed 285 ppm P_2O_5 with no addition of phosphorus. The organic matter was 3.34%.
d. Field 26 soil from Oahu Sugar Company with 200 pounds per acre P_2O_5 added.

recommended that a change be made in plantation practices and that DCMU be used where there has been damage noted from CMU. If necessary, less DCMU can be used than CMU in order to compensate on cost. Simazine has caused less damage to sugar cane than DCMU.

Damage Noted	Tolerance Noted
37-1933	49-5
49-104	50-7209
44-3098	49-3533
38-2915	
39-7028	

Varieties

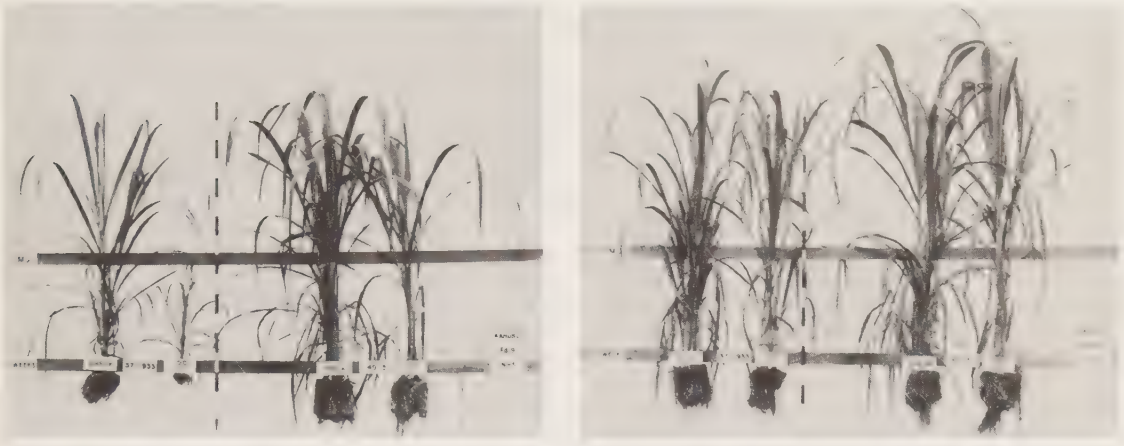
Varieties have been found to vary considerably in reaction to CMU, DCMU and simazine as shown in Figure 66. Listed below are the general reactions to the three chemicals of the varieties on which some information is available.

General

The level of CMU in the soil is not always important in determining damage. Damage to cane has resulted where the level of CMU has been as low as one part per million.

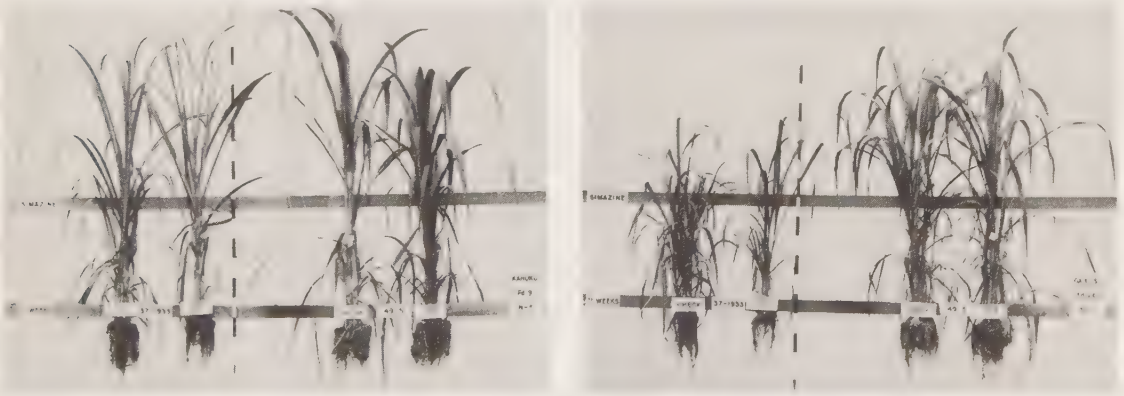
Response to P_2O_5 prompts one to make sure that

Figure 66. Differential tolerance of Varieties 49-5 and 37-1933 to CMU, DCMU and simazine, as well as differential effect of the three herbicides on cane in two different soils.



a. Note difference between effects of CMU on Varieties 37-1933 and 49-5 at the 10 ppm CMU level. Also differences in check.

a and b. Note differential effect of CMU on the two soils from Kahuku and Oahu Sugar. Compare also DCMU effects in c and d and simazine effects in e and f.



a, c and e. Note differential effects between CMU, DCMU and simazine, particularly at the 10 ppm level on Variety 37-1933 on one soil.

a and b. Note levels of application in the two soils and equal growth of cane in each.

c and d. Note similar amount of growth from Varieties 37-1933 and 49-5 in each of the two soils.

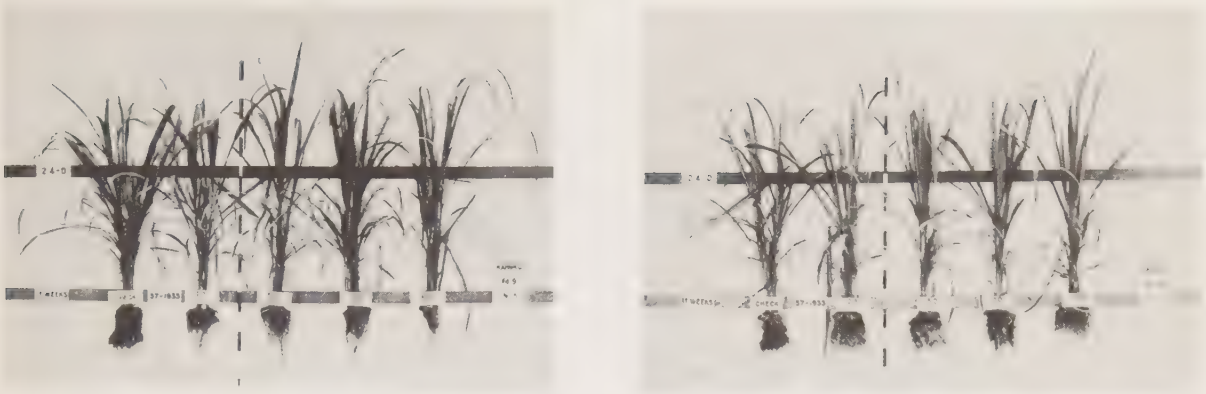
Figure 67. Amino triazole at the indicated levels in soils from Kahuku and Oahu Sugar did not show any deleterious effect on cane growth.

there is adequate phosphorus in the soil, particularly in those trouble spots infield where CMU damage has been observed in the past. The symptoms of CMU or DCMU damage are reduced tillering and chlorosis. The reduced tillering can take place without chlorotic effects.

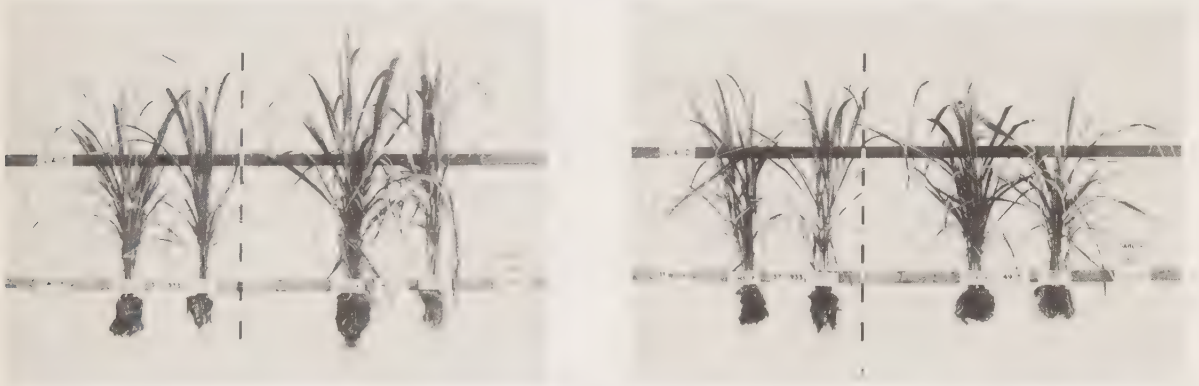
It is re-emphasized that DCMU is safer to use than CMU for pre-emergence control, but slight burns on the foliage have been noted from spraying DCMU over sugar cane. Simazine is safer to use than DCMU, but it is not as yet registered for use in sugar cane.

Table 27. Effect of Dalapon, TCA and CMU on Three Strains of Manienie

			% Kill of Manienie		
Herbicide	Lbs./A	Treatments	Makiki	Honokaa	Kilauea
Dalapon	5	5	95	0	0
	10	5	100	0	0
	20	5	100	0	0
TCA	5	5	25	0	0
	10	5	50	0	0
	20	5	100	0	0
CMU	25	1	100	100	100
	50	1	100	100	100
	100	1	100	100	100
Check	....	....	0	0	0



a and b. Note levels of application in each of the two soils. Growth was equal above ground, with slight reduction in root volume in the Kahuku 9 soil.



c and d. Root volume was reduced slightly on both varieties in the Kahuku soil but not in the one from Oahu Sugar.

Figure 68. At the indicated levels in soils from Kahuku and Oahu Sugar, 2,4-D acid caused only slight damage to sugar cane.

DAMAGE FROM 2,4-D AND AMINO TRIAZOLE TESTED

These two herbicides were applied in the same type of test as that with the CMU, DCMU and simazine above. As shown in Figures 67 and 68, there was no effect on cane from the amino triazole when mixed in the soil. There was only a slight effect of 2,4-D. This was mainly on the root system.

Table 28. Effect of 2,4-D and 2,4,5-T on Two Strains of Honohono

Herbicide	Lbs./A	Treatments	% Kill of Strains From Field 001	% Kill of Strains From Mill
2,4-D, amine	1	1	0	95
	5	1	50	100
2,4,5-T, amine	1	1	75	75
	5	1	100	100

HERBICIDE-TOLERANT SPECIES AND STRAINS APPEAR

Bermuda Grass (Manienie) *Cynodon dactylon*

The three strains of manienie from Kilauea, Honokaa and Makiki, that were previously reported to vary in tolerance to dalapon, have also been treated with TCA and CMU (Figure 69). Table 27 lists the results.

Honohono (*Commelina diffusa*)

A strain of honohono from Field 001 at Paauhau Sugar Company has been studied in comparison with a strain growing outside sugar cane near the mill on the same plantation. The reaction of these strains to 2,4-D and 2,4,5-T are shown in Table 28.

The strain in Field 001 did not respond to 2,4-D in the plantation program, but most of the plants were destroyed through use of 2,4,5-T.

Figure 69. Strains of Bermuda grass (manienie) *Cynodon dactylon* are tolerant to sodium dalapon and sodium TCA but not to CMU. In the first two pictures, the Kilauea and Honokaa strains of manienie show tolerance to dalapon and TCA after five treatments at the indicated levels per acre. In the third picture, 25 pounds or more CMU per acre applied once destroyed all three strains of manienie. In the field, it has been necessary to use levels of 50 to 75 pounds CMU per acre to get adequate destruction of either strain.

WING-LEAVED PASSION FLOWER *PASSIFLORA PULCHELLA* PRESENTS PROBLEM

This species is present in several fields at Kohala and in one field at Ewa. It has been proved highly tolerant to all herbicides applied thus far except methyl bromide applied under cover. This method is too expensive to be used. The next most effective herbicide has been TBA, but several treatments will be necessary to destroy the underground root stocks. At the levels needed to control this plant, TBA has shown rather severe damage to sugar cane.

DEVELOPMENT OF LOW PRESSURE SPRAYING FOR REDUCING DRIFT

Due to the fact that 2,4-D spray drift damage has continued in gardens and other areas near plantation fields, further study has been made of application at minimum liquid pressure. Different nozzles have also been tested for patterns at low pressure. Following are recommended nozzles and minimum pressures for spraying 2,4-D:

Nozzle	Minimum psi	Type Spray	Pattern
11004 (SS) *	5	Fan	Droplet
Parasol #2 (SS)	20	Wide cone	Droplet
Flooding (SS)	2–3	Fan	Droplet
Sprinkler (Sasaki)	5	Series of streams	Streak

*SS = Spraying Systems Co. design.
Sasaki = Developed in cooperation with Sasaki Welding Shop, Honolulu.

Pattern studies have shown that large droplets or streaks are formed from the nozzles and pressures. Some fine droplets are dispersed but these are at a minimum in comparison with sprays at 30 psi or higher pressures.

HERBICIDE APPLICATOR TESTED ON PLANTATIONS

The four-wheel, all-wheel drive, terra-tire equipped unit described briefly in the 1958 Report has been built and is being tested and developed (Figures 70 and 71). It is serving as a means of determining the practicability and economics of a unit built especially for broadcast, interline, and spot spray application of herbicides, and is also serving as a means of testing the terra-tire type of Rolligon tire.

The following modifications have been made as a result of field operation and testing: 1) portions of the frame above the front axle assembly were removed to allow more vertical oscillation of the front wheels over rough terrain; 2) the frame was lengthened 16 inches, giving a wheelbase of 100 inches to increase stability on slopes greater than 28 per cent; 3) a standard hydraulic cylinder three and one-half inch bore, 10-inch stroke, replaced the rotary-type cylinder (Rotac) to give better steering control; 4) a four-speed transmission has been installed, replacing the three-speed transmission for slopes greater than 28 per cent; 5) two new herbicide tanks with combined capacity of 200 gallons have been fabricated and installed to replace the single 150-gallon tank. A tank has been mounted beneath the frame on each side to give a lower vehicle center of weight.

The specifications on the present unit are: 1) gauge 66 inches, wheelbase 100 inches; 2) weight, empty, 5230 pounds; 3) four terra-tires, 36 inches by 20 inches wide with herringbone tread; 4) jeep engine, transmission, and four-wheel drive; 5) travel speeds one-half to 11 miles per hour; 6) power steering; 7) spray pattern, broadcast six lines, interline four lines,

Figure 70. Herbicide applicator set up for interline spray of four rows.

spot solenoid control two lines; 8) herbicide capacity, 200 gallons; 9) over-all width reduceable to nine feet for highway travel; and 10) ground pressure six psi.

Traction of the terra-tires has been very good during the field tests conducted to date. Field conditions were average for unirrigated herbicidal work. However, trial runs were made in very wet conditions. Tests on slopes steeper than 28 per cent will be made with the lower low speed and the lower center of weight.

This unit was operated briefly in furrow-irrigated cane. It was indicated that a wheel-type unit should be a back-and-forth two-way unit in order to avoid 180° turns across the ends of the furrow. The unit travelled nicely on the ridges and crossed furrows satisfactorily at an angle. With the four-wheel drive and the herringbone tread, there was no spinning of wheels or displacement of soil. A 46-inch OD by 24-inch wide terra-tire is now available and may be a better all-round size for work in both flat culture and surface irrigation.

HERBICIDE APPLICATOR (MINIMUM)

Ideas for a minimum spray machine were explored by means of preliminary design layout using the minimum of three wheels and two-wheel drive; however, some tests with the existing herbicide applicator indicated rather conclusively that the unit must be all-wheel drive. Also, tires less than 36 inches in diameter and 20 inches wide would increase the problems of maneuverability and would probably be more helpless in wet conditions. This work can be continued if and when the results of the minimum unit could be considered promising.

Figure 71. Herbicide applicator spraying four interlines.

PERSONNEL TRAINING

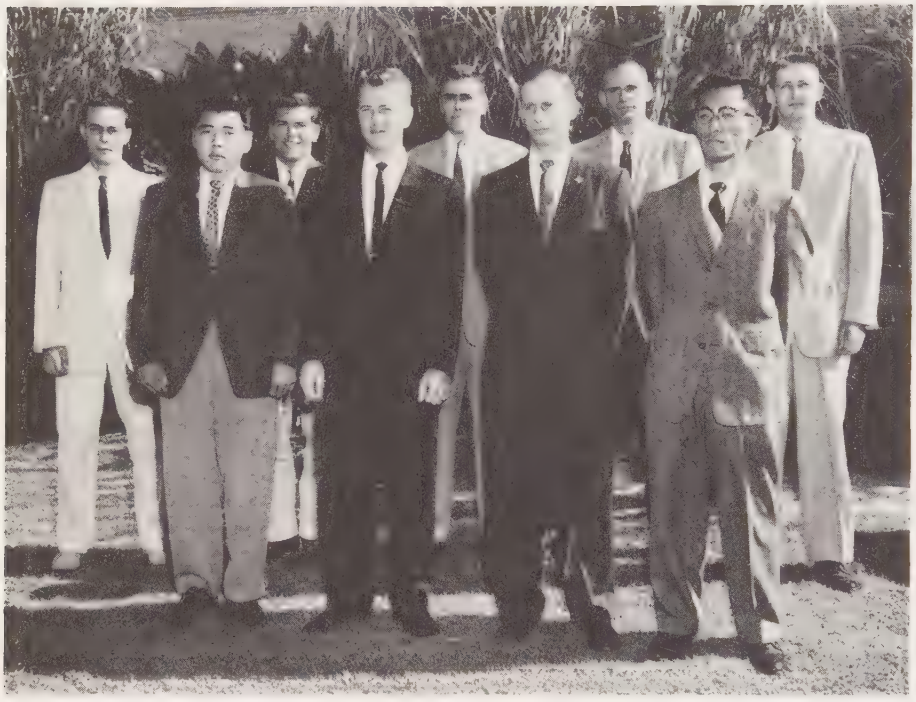


Figure 72. Assistants-in-Training for Agriculture: David W. Pratt, Ronald N. Togashi, Charles T. Fisher, Jack P. Nelson, J. Franklin Johnson, James P. D. Thropp, Jr., Harold F. Eichelberger, George H. Kitamura, Richard F. Cameron.

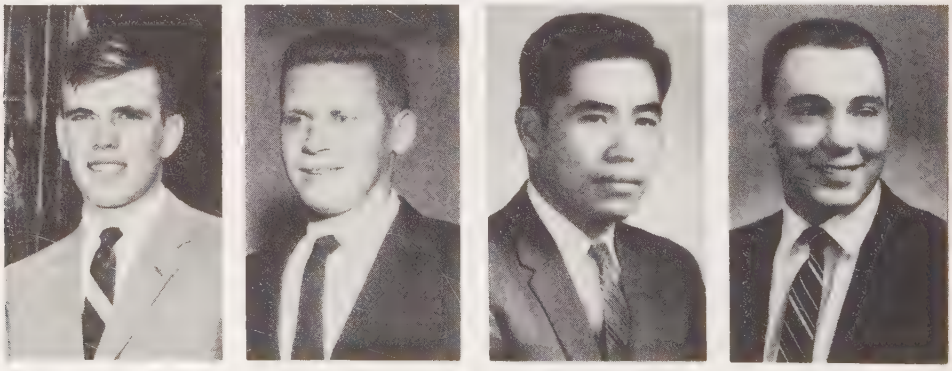


Figure 73. Assistants-in-Training for Sugar Technology: Stuart P. Byam, Keith Holderman, Thomas M. Ikehara, Theodore W. Vorfeld.

Figure 74. Plantation Enrollees for Short Course in Agriculture: Jan Newhouse, Dale Anderson, Ray M. Gill, Sadao Zenigami, Sunny S. G. Kim.

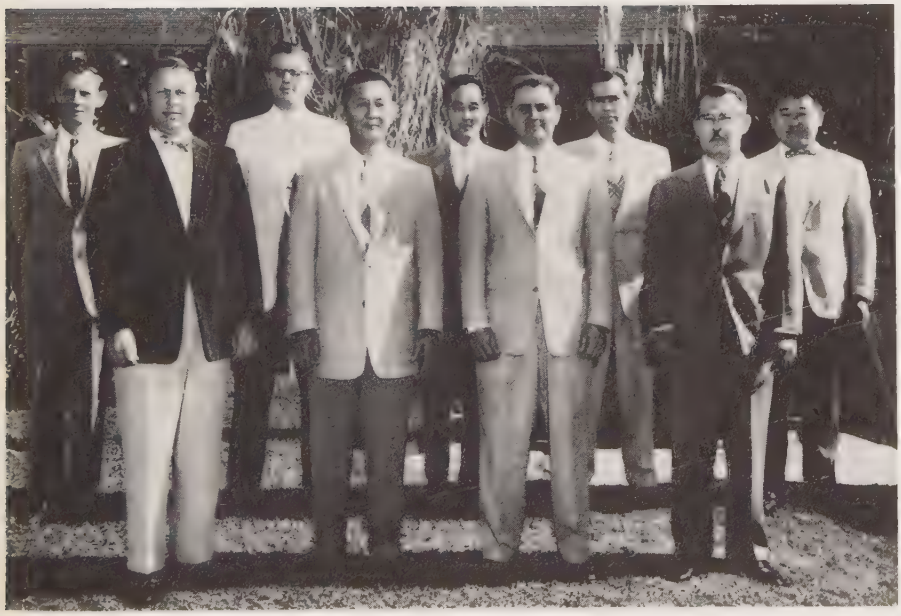


Figure 75. Plantation Enrollees for Short Course in Factory Technology: Ronald S. Cushnie, Robert S. Baxter, P. Douglas Cheape, John M. Sato, Shizuo Sumida, Clark V. Kennedy, Joseph Silva, Amos Ignacio, Tooru Yagawa.

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